Evaluation of Emergency and Critical Care Medicine residents’ diagnostic accuracy in lung ultrasound interpretation in Addis Ababa, Ethiopia: a cross-sectional study at two public teaching hospitals

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Abstract

**Background:** Point of Care ultrasound is defined as a goal-directed ultrasound exam performed by the treating physician to answer a well-defined question relevant to the immediate care of a patient. Currently, lung ultrasound is increasingly used in critically ill patients as an alternative to bedside chest radiography. Point of care ultrasound is a mandatory training for emergency and critical care physicians but there are no published papers on the diagnostic accuracy of lung ultrasound performed by emergency medicine residents. This study aims to assess the diagnostic accuracy of emergency medicine residents' chest ultrasound interpretation at two public hospitals in Addis Ababa, Ethiopia.

**Methods:** A cross-sectional study targeting senior emergency residents in two hospitals in comparison with radiologists. The study was conducted from June 2022 to August 2022 by using a structured questionnaire. There were a total of 70 emergency residents at these hospitals. The completed data was coded, manually checked, and exported to SPSS version 25 for data analysis.

**Results:** 60 emergency and critical care medicine residents were enrolled in this study among which 28 (46.7%) were from Addis Ababa University and 32 (53.3%) were from St. Paul's Hospital Millennium Medical College. The overall accuracy in the interpretation of chest ultrasound was low. The sensitivity of residents in detecting normal chest ultrasounds was 95%. Most residents correctly identified pneumothorax at 96.7% and the lowest rate of interpretation was lung metastasis at 5%. There is a moderate agreement between emergency residents and radiologists (kappa 0.4). There is no factor identified that has a significant association with the outcome of interpreting chest ultrasound scans.

**Conclusion:** The skills of residents in interpreting chest ultrasound results are low regardless of the prevalence of the condition in the emergency room or the relative clinical importance of the condition. Poor sensitivity results with misinterpretations were common.

**Recommendation:** we recommend the need for continuous training and assessment of the residents on lung ultrasound scanning. Further studies should be done, to fill the gaps and improve the quality of teaching.

**Introduction / Background**

The utilization of point-of-care ultrasound (POCUS) in the emergency department has come a long way from 1994 when the first emergency medicine ultrasound curriculum was incorporated into the current core competency in emergency medicine training programs (1).

When carried out by a skilled doctor at the patient's bedside, ultrasound is non-invasive, free of ionizing radiation, affordable, and quick. As a result, it has become an extensively utilized tool. POCUS has frequently been demonstrated to alter the initial diagnosis, boost doctors' confidence in making the leading diagnosis, and increase diagnostic precision (2).
The benefits of using bedside lung ultrasonography correctly in an emergency patient care are astounding, especially when it comes to reducing radiation exposure, postponing or even skipping transportation to the radiology unit, and directing life-saving treatments in the direst of circumstances (3).

To evaluate the effect of bedside lung ultrasound on physician clinical decision-making in the emergency department, Darlene R. House and colleagues conducted a prospective cross-sectional study in Nepal. Twenty-two clinicians took part in the study and performed 280 lung ultrasounds. Of the patients with dyspnea, 124 (44.3%) had a new diagnosis. In 150 patients (53.6%), doctors reported changing the management based on lung ultrasonography. Treatment accounted for the bulk of management changes (83.3%), followed by disposition (13.3%), and new consultations (2.7%). This study found that bedside lung ultrasonography had a significant impact on physician clinical decision-making, particularly in terms of patient diagnosis and treatment, in an emergency department in Nepal (4).

POCUS training is currently a required component of emergency medical training and is widely used in emergency rooms. A qualified emergency physician must be adept at taking and interpreting images as well as applying test results (5).

While dedicated postgraduate emergency medicine residency training programs are now available in different countries, there is currently no agreement on the core POCUS competencies. In 2017, Salmon et al. published a paper outlining regionally relevant training curricula and provider core competencies for POCUS education on the African continent. The five main strategic concerns presented are to link training programs with hospital systems, prioritize longitudinal learning models, share resources to promote health equity, maximize access, and build a regional consensus on training standards and credentialing (6).

In 2018 research by Wanjiku and colleagues evaluated an innovative POCUS training program for Kenyan rural healthcare providers. Twenty-one separate facilities evaluated thirty-three trainees. The written exam was passed by every student, while 32 trainees passed the OSCE. 33 trainees, or 27.3%, had 33 trainees who passed the written exam. While those who had only one prior training session saw no change in their written test results, those who had two or more prior training sessions had statistically significant improvements. There was no statistically significant correlation between the amount of time since the last training and mean written exam scores (7).

Maja Stachura and colleagues evaluated a POCUS ultrasound scan list in a resource-constrained emergency medicine center in Addis Ababa, Ethiopia, and reported their findings in the African Journal of Medicine in 2017. They enrolled a convenience sample of 118 patients who had clinical indications for POCUS. The results have subsequently been used to develop a locally relevant emergency department ultrasound curriculum for Ethiopia's first emergency medicine residency program (8).

According to a new international statement drafted by specialists from twelve critical care associations, POCUS training for critical care physicians is the requirement. Despite increased attention, there is little consistency in the approaches used by centers to promote the development of these competencies (9).
Most emergency medicine residency programs provide training on emergency physician performed ultrasound in emergency department but the performance of ultrasound by emergency physicians is not known.

**Methods**

**Study design and study population**

The study was conducted in Addis Ababa, at AAU (TASH) and SPHMMC. Addis Ababa University was established in 1950 and the faculty of Medicine was formally approved on March 26, 1963. The post graduate training program began in 1979 G.C. The department of emergency medicine was formed at Tikur Anbessa specialized hospital (TASH) in collaboration with AAU, the university of Wisconsin, and the university of Toronto in 2010 G.C.

St. Paul's Hospital Millennium Medical College was formed in 2010. It is governed by a board under the federal ministry of health. Saint Paul University established emergency department in the year 2011 G.C.

Residency was given over a period of three years in both faculties; both settings have two ultrasound machines in the emergency room. The trainings are given by senior attendings in both setups with a similar curriculum.

A cross-sectional study of emergency medicine residents conducted in 2022 from June - August 2022.

The source of population in this study is all residents training at AAU and SPHMMC.

The study population is Emergency and critical care medicine residents of AAU and SPHMMC available at the time of the study.

Sample population was taken from the residents, who participated on the study, sample size was determined using the formula for cross-sectional study.

\[
\text{Sample size} = Z_{(1-a/2)}^2 \times P(1-P) / D^2
\]

\[Z_{(1-a/2)} = \text{the value under the standard normal table fora given confidence interval (1.96 for 95\% CI).}\]

\[P = \text{Expected proportion in population based on previous or pilot studies. P is the best estimate of prevalence since we don’t have a previously done study in our country; we took 50\% to increase the strength of the study.}\]

\[D = \text{the margin of error (0.05)}\]
n = (1.96)² * 0.5(1-0.5) / (0.05)² = 384

n = the minimum required sample size

Since our source population is 70, we used the correction formula where n is the sample size we calculate (384), N is our total population (70)

Corrected sample size = n*N / n+N = 59

Adding 10% non-response rate, the sample size calculated is 65.

All emergency and critical care medicine residents who were attending their residency program at SPMMC & TASH were included and residents who were not willing or unable to participate in study were excluded from the study.

After calculating the sample size, we used random sampling method to randomize the population as we already have a complete list of every study population. Using the random number method, we assigned every population a number and they randomly picked a subset of population.

The dependent variable was Diagnostic accuracy of emergency residents in chest ultrasound interpretation while the independent variables were POCUS training, enough training, and school, level of residency, sex, confidence, and satisfaction of the training.

**Operational definitions**

**Diagnostic accuracy** – previous study done on basic competence in lung ultrasound, defined accuracy of 80% out of twenty to twenty five examinations (10, 11).

**Senior residents** – Residents who are on their second and third year of residency study. The second years are residents are those who completed the first 6 months of their study year.

**POCUS training** – either online or in-person training on POCUS interpretation

**Data collection tools and procedure**

Chest ultrasound videos were selected from ultrasound online sites, blogs, and some were acquired at bedside in our hospital by blinded radiologists. The questionnaire was created and structured and was put on Google form. The questionaries include basic information of the residents and POCUS ultrasound
videos focusing on common life-threatening events which occur in the emergency department. Pretested and structured questionnaire was distributed to the study population.

The examination includes A lines, B lines, barcode sign, comet tail, dynamic and static air bronchogram, hepatization, lung point, lung pulse, lung sliding, seashore sign, hydropneumothorax, empyema, lung abscess, pleural effusion, pneumonia, pulmonary edema, COPD, atelectasis, subcutaneous emphysema, lung malignancy and rib fracture videos.

The videos were interpreted by radiologist with cardiothoracic imaging subspeciality, emergency medicine consultant with ultrasound subspeciality, and emergency medicine consultants who is doing fellowship in point of care ultrasound. Interpretations from the specialists were used to standardize the POCUS interpretation, and two similar answers were used as the correct answer of the POCUS reading. The POCUS ultrasound videos were forwarded to the residents though online platforms and they submitted their interpretations.

Data collection was primarily done by the principal investigator, and the responses were checked for completeness of the data before inserting them to SPSS software. Pretest was performed on 3% of the study population using online questionnaire.

The completed questioners were coded, manually checked, and entered to Microsoft Excel and exported to SPSS version 25 for cleaning and analysis by the principal investigator. Descriptive statistics, proportion, mean, and chi-square test were calculated and using tables and charts to characterize the study population using socio-demographic and background characteristics. To identify factors associated with competency in lung ultrasound interpretation bivariate logistic regression analysis was done. Crude odds ratio with 95% Confidence interval was calculated to determine the presence and strength of association. Statistical significance was set at P-value of 0.05. Descriptive analysis, binary logistic regression, area under ROC and Cohen's kappa was used to produce a summary of statistics.

Data collection was started after getting written permission from the ethical review committee of the Department of emergency medicine and critical care, TASH, Addis Ababa University. Informed consent was taken from participants upon filling the questionnaire and they have given consent with a signature and confidentiality of the information was insured by filling the questionnaire anonymously.

Results

Characteristics of study participants

Of the sixty-emergency medicine and critical care residents enrolled, the mean age range of twenty-nine to thirty years. 47 (78.3%) of the participants were male. 32 (53.3%) of the participated were from SPHMMC.
Considerable number of residents who participated in this study were year two residents (N=34, 56.7%) followed by year three residents (N=26, 43.3%).

26 (43.3%) of the residents had POCUS training in the first year of their residency while 11(18.3%) of the residents said to have classes on year 2. Of those who attended 33(55%) of them have attended all POCUS classes. 23 (38.3%) of the residents claimed to have no POCUS training at all. Out of the sixty residents, 55 (91.7%) of them said the POCUS training was not enough to independently perform the examinations.

38 (63%) of the residents rated their confidence level of chest ultrasound interpretation as confident while 21 (35%) of the residents rated their confidence level as neutral and 2 % not confident.

55 (91.7%) of the residents usually ask for help during POCUS examination and senior residents were mentioned as a source of help by 30 (50%) of the participants followed by consultants 21 (41.7%) and radiologists 5 (8.3%).

Apart from one participant, all said that nothing bad has ever happened because of their chest ultrasound interpretation. And 30(50%) of the residents labeled their satisfaction with the current POCUS training as good.

No single resident correctly identified 80% (16 and above) cases of chest ultrasounds. The maximum score was 15/20 (75%) and the minimum score was 3/20 (15%) cases. The average score was 10.6 (53%). The most correctly interpreted case was pneumothorax which 96.7 % (95% CI) of the residents got it correctly and the second most answered cases were pulmonary edema and normal lung sliding, they were answered by 57 residents out of the 60 residents 95% (95% CI).
Chest ultrasound findings interpretation

We used ROC curve to calculate the accuracy of the respondents in correctly interpreting a given chest ultrasound scan as it drawn below in figure, the area under the receiver-operating curve has become 0.575. Thus, the ECCM residents interpret chest ultrasound scans with the accuracy of 57.5% (95% CI).

We have done the ROC for ECCM residents in the correctly interpret normal chest ultrasound scan. The AUROC 0.736, thus the accuracy of ECCM residents in interpreting normal chest ultrasound scan is 73.6% with the specificity 89.2%, sensitivity 82%.

Cohen's kappa is used to calculate the rate of agreement between the emergency resident and the cardiothoracic radiologist. An agreement of zero means that there's no significant agreement, no more than would have been expected by chance. An agreement of >=0.5 is considered a good agreement; a value of 0.7 shows a very good agreement. An agreement of one means there's a perfect agreement. The kappa value for each chest ultrasound scan was calculated and with the highest kappa of 0.4 (CI-95%) which is a moderate agreement and the lowest kappa of 0.3 (CI-95%) which is a fair agreement for pneumothorax and collapse consolidation respectively.

When we see participants score and year of residency, 50% of year two residents scored <50%, while 19% of year 3 residents scored below 50%.
<table>
<thead>
<tr>
<th>Chest ultrasound findings</th>
<th>YEAR 2</th>
<th>YEAR 3</th>
<th>P - values</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Correct</td>
<td>Incorrect</td>
<td>Correct</td>
</tr>
<tr>
<td>Lung hepatization</td>
<td>4 (11.8%)</td>
<td>30 (88.2%)</td>
<td>4 (15.4%)</td>
</tr>
<tr>
<td>B-lines</td>
<td>32 (94.1%)</td>
<td>2 (5.9%)</td>
<td>24 (92.3%)</td>
</tr>
<tr>
<td>Dynamic air bronchogram</td>
<td>10 (29.4%)</td>
<td>24 (70.6%)</td>
<td>4 (15.4%)</td>
</tr>
<tr>
<td>Empyema</td>
<td>9 (26.5%)</td>
<td>25 (73.5%)</td>
<td>11 (42.3%)</td>
</tr>
<tr>
<td>Lung consolidation</td>
<td>14 (41.2%)</td>
<td>20 (58.8%)</td>
<td>18 (69.2%)</td>
</tr>
<tr>
<td>Hydropneumothorax</td>
<td>5 (14.7%)</td>
<td>29 (85.3%)</td>
<td>5 (19.2%)</td>
</tr>
<tr>
<td>A-lines</td>
<td>29 (85.3%)</td>
<td>5 (14.7%)</td>
<td>26 (100%)</td>
</tr>
<tr>
<td>Lung pulse</td>
<td>8 (23.5%)</td>
<td>26 (76.5%)</td>
<td>11 (42.3%)</td>
</tr>
<tr>
<td>Lung sliding</td>
<td>26 (76.5%)</td>
<td>8 (23.5%)</td>
<td>23 (88.5%)</td>
</tr>
<tr>
<td>Lung abscess</td>
<td>6 (17.6%)</td>
<td>28 (82.4%)</td>
<td>9 (34.6%)</td>
</tr>
<tr>
<td>Lung metastasis</td>
<td>0 (0%)</td>
<td>34 (0%)</td>
<td>3 (11.5%)</td>
</tr>
<tr>
<td>Lung point</td>
<td>22 (64.7%)</td>
<td>12 (35.3%)</td>
<td>20 (76.9%)</td>
</tr>
<tr>
<td>Normal lung sliding</td>
<td>32 (94.1%)</td>
<td>2 (5.9%)</td>
<td>25 (96.2%)</td>
</tr>
<tr>
<td>Chest wall mass</td>
<td>4 (11.8%)</td>
<td>30 (88.2%)</td>
<td>2 (7.7%)</td>
</tr>
<tr>
<td>Pleural effusion</td>
<td>25 (73.5%)</td>
<td>9 (26.5%)</td>
<td>20 (76.9%)</td>
</tr>
<tr>
<td>Pneumothorax</td>
<td>32 (94.1%)</td>
<td>2 (5.9%)</td>
<td>26 (100%)</td>
</tr>
<tr>
<td>Pulmonary edema</td>
<td>31 (91.2%)</td>
<td>3 (8.8%)</td>
<td>26 (100%)</td>
</tr>
<tr>
<td>Variable</td>
<td>Crude odds ratio</td>
<td>95% confidence interval for crude odds ratio</td>
<td></td>
</tr>
<tr>
<td>--------------------------</td>
<td>------------------</td>
<td>---------------------------------------------</td>
<td></td>
</tr>
<tr>
<td>Rib fracture</td>
<td>5 (14.7%)</td>
<td>29 (85.3%)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>1 (3.8%)</td>
<td>25 (96.2%)</td>
<td></td>
</tr>
<tr>
<td>Subcutaneous emphysema</td>
<td>9 (26.5%)</td>
<td>25 (73.5%)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>9 (34.6%)</td>
<td>17 (65.4%)</td>
<td></td>
</tr>
<tr>
<td>Lung collapse</td>
<td>18 (52.9%)</td>
<td>16 (47.1%)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>16 (61.5%)</td>
<td>10 (38.5%)</td>
<td></td>
</tr>
</tbody>
</table>

The Association of different independent variables with chi-square and binary regression was done. Independent variables such as place of postgraduate training, year of residency, level of confidence, sex of the residents, satisfaction, and POCUS training were analyzed.

Statistically, a significant difference has been shown in accuracy in interpreting lung consolidation by year three residents compared to year two residents with a P-value of 0.013. Those students who had POCUS training also interpreted lung abscesses more accurately P-value of 0.045, and residents from SPHMMC interpreted lung point more accurately and it was found to be statistically significant with a P-value of 0.045.

### Table 3: the odds ratio of correct interpretation of chest ultrasound scans by ECCM residents

<table>
<thead>
<tr>
<th>Variables</th>
<th>P-value</th>
<th>Crude odds ratio</th>
<th>95% confidence interval for crude odds ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sex</td>
<td>0.096</td>
<td>0.313</td>
<td>0.076 1.284</td>
</tr>
<tr>
<td>School</td>
<td>0.265</td>
<td>1.800</td>
<td>0.637 5.083</td>
</tr>
<tr>
<td>Training</td>
<td>0.016</td>
<td>3.792</td>
<td>1.255 11.455</td>
</tr>
<tr>
<td>Year of training</td>
<td>0.740</td>
<td>1.286</td>
<td>0.291 5.672</td>
</tr>
<tr>
<td>Attending trainings</td>
<td>0.024</td>
<td>3.345</td>
<td>1.150 9.733</td>
</tr>
<tr>
<td>Enough training</td>
<td>0.432</td>
<td>0.479</td>
<td>0.074 3.102</td>
</tr>
</tbody>
</table>

**Discussion**

Point of care ultrasound is a useful imaging technique for the emergency physician. The emergency physician can quickly evaluate patients with respiratory failure using an ultrasound of the thorax to look
for normal aeration patterns, pneumothorax, consolidation, and pleural effusion as a superior tool than chest radiography (11).

Maja Stachura and colleagues evaluated a POCUS ultrasound scan list in a resource-constrained emergency medicine center in Addis Ababa, Ethiopia, and reported their findings in the African Journal of Medicine in 2017. They enrolled a convenience sample of 118 patients who had clinical indications for POCUS. There were 42% females and a mean age of 35. In total, 118 patients underwent 338 scans for 145 different purposes. Pericardial scans (n = 78; 23%), abdominal free fluid scans (n = 73; 22%), pleural effusion/hemothorax scans (n = 51; 15%), inferior vena cava scans (n = 43; 13%), pneumothorax scans (n = 38; 11%), and global cardiac activity scans (n = 25; 7%) were the most frequently performed scans. One hundred and twelve (95%) POCUS scans produced data that was therapeutically helpful. 53 individuals (45%) had ultrasonography results. These findings suggest POCUS plays a vital role in patient management and disposition decisions (8). This has strong relevance for lung ultrasound as most patients are still difficult to move to radiography rooms while they are on oxygen support or quite critical for transportation.

A study published by Darlene R. House and et al in 2021, Only 19 physicians participated in this study, and after performing roughly five independent examinations against experts, 18 of them (95%) attained proficiency. This study used a previously accepted threshold to determine learner competency and suggested the physician must be at least 70% accurate to be competent. According to this research, a lung ultrasound test is among the simpler ultrasound exam types to conduct and interpret (12).

There are multiple studies suggesting 20-25 supervised scans are required to acquire basic skills for interpretation of lung ultrasounds. In our emergency department senior residents perform multiple scanning and have gotten training during their junior year (12, 13).

It is known that test's accuracy is demonstrated by the AUROC. The only test that is 100% sensitive and specific and has an AUROC of 1 is the ideal test. Since this is infrequently observed in practice, we consider that the closer it is to 1, the more accurate it is when the ROC is dragged further to the left. A value between 0.5 and 0.7 is regarded as having low accuracy, whereas a score less than 0.5 indicate the test is completely inaccurate.

Results with a 0.7 or higher have medium to high accuracy. In our study, ECCM residents' accuracy in interpreting chest ultrasound videos was 0.575, which is a low accuracy rate. These differences may be due to variations in sample size, study methodology, the lack of clinical data, and/or the degree of training of residents and unlike previous studies that were mostly done on emergency physicians and anesthesiologists this study is done on emergency residents only.

The kappa value for each chest ultrasound scan was calculated and with the highest kappa of 0.4 (CI-95%) which is a moderate agreement and the lowest kappa of 0.3 (CI-95%) which is a fair agreement for pneumothorax and collapse consolidation respectively. These findings indicate that resident's accuracy doesn't increase linearly as they advance through the program, which may be because there isn't
continuous training in this area. There is no statistically significant difference between the year of residency and the reading level.

Magdalena Szumilas published a paper titled explain Odds ratio, the odds ratio can be used to analyze the relative importance of different risk factors for a given outcome and to ascertain whether a specific exposure is a risk factor for that event. OR=1 shows, exposure doesn't affect odds of outcome, OR>1 shows exposure associated with higher odds of outcome, OR < 1, indicates an exposure associated with lower odds of outcome. Based on this, our study found that, place of postgraduate training, receiving POCUS training, year of training and attending all trainings have been found to increase the odds of correctly interpreting chest ultrasound scans (14).

**Limitations of the study**

It did not include all cases of chest ultrasound videos as only common conditions were included. The questionnaire was filled during working hours and duty hours thus residents may not give full attention due to fast changing nature of study environment. Patient’s clinical data were not given in this study, and effect of knowing clinical condition is not studied. Probe placement is not given in the study, so its effect is not known. We couldn’t find all the ultrasound images from our patients so, we had to take most videos from ultrasound sites. With increased years of training and experience comes a clear difference in the interpretation of chest ultrasound images.

**Conclusion**

The skills of residents in interpreting chest ultrasound results are low regardless of the prevalence of the condition in the ER or the relative clinical importance of the conditions. ECCM residents have moderate agreement with the cardiothoracic radiologist in accurately interpreting chest ultrasound scans. The residents are confident enough on their interpretation of the chest ultrasound videos. All residents want additional training and believe the current training is inadequate.

**Abbreviations**

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
</tr>
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<tbody>
<tr>
<td>AAU</td>
<td>Addis Ababa University</td>
</tr>
<tr>
<td>ARDS</td>
<td>Acute Respiratory Distress Syndrome</td>
</tr>
<tr>
<td>AUC</td>
<td>Area under the curve</td>
</tr>
<tr>
<td>CI</td>
<td>Confidence Interval</td>
</tr>
<tr>
<td>COVID</td>
<td>Corona Virus Disease</td>
</tr>
<tr>
<td>CT</td>
<td>Computed Tomography</td>
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</table>
Declarations

Ethical approval and consent to participate – Ethical clearance is obtained from Emergency Medicine Department research ethics committee of School of Medicine, College of Health Sciences at Addis Ababa University.

Consent for publication – All authors fully consented for this publication submission. The authors declare that preprint has previously been published (16).

Availability of data and materials – All finding data’s are incorporated in the study and further availability is based on reasonable request.

Competing interests – The authors declare that they have no competing interests.

Funding – All funding is provided from Addis Ababa University for the principal investigator upon department approval.

Author’s contribution – All authors equally contributed for this research paper. BK, TB, SK, TZ and BT analyzed and interpreted the patient data regarding the hematological disease and the transplant. BK did the main research, and was a major contributor in writing the manuscript. All authors read and approved the final manuscript.

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References


Figures
Figure 1

The percentile of incorrectly answered cases of chest ultrasound by participants.
Figure 2

The percentile of correctly answered cases of chest ultrasound by participants.
Diagonal segments are produced by ties.

Figure 3

The ROC of the accuracy rate of ECCM residents of AAU & SPHMMC
Figure 4

The ROC on the interpretation of Normal chest ultrasound scans of ECCM residents of AAU & SPHMMC