Abstract

Introduction: The Focused Assessment with Sonography in Trauma (FAST) is a Point of Care Ultrasound (PoCUS) study that is routine in trauma patient assessment. Many organizations have published training guidelines, which grant competency through the completion of a fixed number of observed scans. This approach is incongruent with current trends in competency-based medical education. We aim to objectively quantify probe motion and user accuracy to differentiate groups of PoCUS operators.

Methods: Emergency medicine residents were recruited in two groups. The novice group (n=15) had limited PoCUS experience; whereas the intermediate group (n=14) had completed at least 50 supervised FAST examinations. Both groups underwent assessment on a live human model. Residents from the novice group returned (n=9) after completing a curriculum, and repeated the assessment using the identical experimental construct.

Results: Significant differences ($p<0.05$) were found between the novice, and both the intermediate and novice returned groups in time, path length, and points of interest (POIs) scanned. Novices required more time to complete the full exam (290.82s vs 197.41s vs 271.79s), utilized more motion (9392.07mm vs 4052.73mm vs 4985.05mm) and imaged fewer POIs (48.13% vs 95.00% vs 100.00%) when compared to intermediates and returning novices, respectively. No difference was found between the intermediate and novice returned groups for the complete exam. Spearman's correlation was calculated between variables within each group. Correlations between time and path length were statistically significant ($p<0.05$) with novice, intermediate, and novice returned values of 0.67, 0.65 and 0.90. Interestingly, neither time nor path length consistently correlated with POIs scanned in any group.

Conclusion: Differences in probe motion efficiency and POIs scanned between novices and intermediate or returning novice users show promise for use as a quantitative objective assessment tool. Unlike in surgical literature, accuracy did not correlate with path length or time to exam completion.

Introduction

Point of care ultrasound (PoCUS) is part of the standard assessment of a variety of emergency department presentations. The Focused Assessment with Sonography in Trauma (FAST) exam is a well-accepted PoCUS core competency (1,2). With the advent of competency-based medical education (CBME), there is a need for objective assessment of PoCUS skills, and currently there are only a few prospective studies using objective tools to assess expertise in this area (3, 4). Skill assessment completed by instructors are both resource intensive and subject to human error. Alternatively, automated objective assessment instruments have been developed and shown successful in assessing other procedural skills such as lumbar puncture, central line insertion and motion economy for the FAST exam (5-7). To date, there is no widespread computerized accuracy metric for the critical assessment of PoCUS skills on live models. An automated objective accuracy assessment instrument may provide a more precise estimation of learner ability, better opportunity for skill enhancement and further training. These improved skills could lead to better patient care while reducing or eliminating the need for intensive instructor supervision.

Procedure-based studies from the surgical literature suggest that objective skill evaluation metrics can clearly differentiate novices from experienced users (8-10). These studies demonstrate that skilled users possess more efficient and economic hand motion when compared to novices, as evidenced by measurably shorter hand motion path lengths and time to task completion.

The purpose of this study was to assess whether the measurement of probe motion, time required to complete the exam and points of interest (POIs) scanned would provide an objective evaluation of expertise in learners performing a FAST exam on a single live human model. We adapted an automated objective skill assessment tool previously utilized in other settings (5,6), and hypothesized that novice users performing a FAST exam would use more probe motion, and time to complete the exam, while scanning fewer POIs than the intermediate group. We further believed that novices' parameters would approach those of the intermediate group after a period of focused practice.

Methods

Study design and setting

We conducted a prospective cohort study comparing the ultrasound probe motion and scanning accuracy of two populations of emergency medicine residents performing a PoCUS FAST exam. Data were collected over 3 sessions at the Queen's University Clinical Simulation Centre using a single live human model. The Queen's University institutional research ethics board approved the study (No: **6012484**).

Selection of participants

A convenience sample of twenty-nine volunteer emergency medicine residents known to have varying PoCUS experience were recruited in person, and separated into two groups. The novice group (n=15) had limited prior PoCUS exposure, with all having reviewed a standardized structured didactic curriculum as part of residency education. The intermediate group (n=14) had already completed the identical standardized didactic session and performed at least 50 supervised FAST examinations on emergency department patients in accordance with the Canadian Point of Care Ultrasound Society guidelines (2). Any resident who had previously initiated or completed a structured hands-on PoCUS curriculum that was not affiliated with (insert location) was excluded from the study.

At the conclusion of the academic year, nine members of the novice group returned after having performed at least 50 observed FAST exams on live patients. The six novice participants who were not reassessed had either not completed the required number of practical scans (n=1), or were unable to be present for the follow-up assessment (n=5). The intermediate group was not reassessed, as the overwhelming majority of participants were unavailable at the time of the final assessment.

Measures

All tools were tracked using an NDI TrakStar electromagnetic tracking system (Northtern Digital Inc., Waterloo, ON) with a medium range field generator and Model 800 sensors. One sensor was firmly affixed to the model's lumbar region. A second sensor was fixed to the ultrasound probe. This was calibrated to the ultrasound imaging plane according to the tracked pointer method suggested by Welch (11). Ultrasound probe motion was tracked in three dimensions by comparing its position relative to the stationary reference sensor on the model within the electromagnetic field. (Fig 1) Provided the stationary reference sensor has not changed position with respect to the models anatomy, all measured values would be consistent regardless of position.

Unlike a physical task that is complete when the user has accomplished all of the tangible steps, there is no concrete end point to the FAST exam. The task is complete when the operator believes that they have examined all the areas of interest sufficiently, so we elected to virtually define key points of interest within our model as a measure of scanning accuracy. In order to do this, a PoCUS fellowship-trained physician first performed a FAST exam on the single model. The image sequences were analyzed and points of interest were placed on the series of still images in each region. These points were placed at the key anatomical areas that define a complete FAST exam (12). By recreating these points in 3D space, it was possible to measure how many of these points the US beam had intersected for each portion of the FAST exam.

Using the experimental setup described, novice and intermediate residents performed a FAST exam scanning each region of interest. The tracking and image recording was conducted simultaneously for each region using the open-source SlicerIGT (www.slicerigt.org) platform with the embedded PLUS software library (www.plustoolkit.org) (13). Images were recorded directly from the ultrasound machine. The identical experimental construct was replicated one year later for the returning novices after they had completed at least 50 observed FAST examinations.

The resident FAST exam results were compared to the original expert sonographer's POIs using the open-source Sequences extension for 3D Slicer (www.slicer.org). The US beam plane was reconstructed using SlicerIGT to calculate whether a specific POI was interrogated during the resident's exam. A small 10mm error threshold was created around each POI to account for breathing, deformation and US beam width. All metrics were calculated automatically by the open-source Perk Tutor software (www.perktutor.org) (14).

The variables used in analyses included path length in millimeters, time to completion of the exam in seconds and the proportion of POIs scanned.

Statistical analysis

The data generated by the experimental construct was assessed for normality and analyzed using the Wilcoxon rank sum test at an alpha level of 0.05 using Matlab (MATLAB, The MathWorks Inc., Natick, MA). A Spearman's rank correlation coefficient was generated to evaluate the relationship between the different measured variables.

Results

In general, novices required more time to complete the exam, displaying greater probe motion and less accuracy in percentage of POIs scanned, when compared to the intermediate and novice returned groups with rare exceptions.

Novice group compared to the intermediate group

A significant difference was found at the $p<0.05$ level between the novice and intermediate cohorts in the RUQ for median time to complete the segment 80.65s vs 55.39s, path length used to complete the section 1586.10mm vs 707.64mm and POIs scanned 50.00% vs 100.00% in the RUQ. All RUQ values were significant. In the LUQ the novice users required a lower median time to complete the section 60.59s vs 74.83s, utilized a longer median path length 2719.55mm vs 1385.97mm, and imaged fewer median POIs 40.00% vs 100.00% when compared to the intermediates. The time and path length in the LUQ were not statistically different, while the difference in POIs scanned was significant at the $p<0.05$ level. In the pericardium the novice group required more time to complete the section 52.66s vs 35.37s, used a longer path length 1362.56mm vs 563.75mm and had fewer median POIs scanned 37.50% vs 100.00% when compared to the intermediate group. In the pericardium the differences between groups in time and path length were statistically different while the difference in POIs scanned was not statistically significant. In the pelvis the differences in time and path length differences were statistically significant. Novices required 60.42s vs 26.26s to complete the segment using 1498.42mm vs 678.45mm when compared to the intermediates. Both the novice and the intermediate groups had a median value of 100.00% of the POIs scanned in, however there was a statistically significant difference with the intermediate group outperforming the novice group. When all regions were added together, novices used more time 290.82s vs 197.41s and path length 9392.07mm vs 4052.73mm while having less POIs scanned 48.13% vs 95.00% when compared to the intermediate group. All values were significantly different, with novices underperforming compared with the intermediates. (Table 1)

Novice group compared to the novices returned

In the RUQ the novice group used a median of 80.65s vs 121.59s and 1586.10mm vs 1739.42mm compared to the novice returned group to complete the segment. None of these values was statistically different. However novices had a median of 50.00% of POIs scanned whereas the novice returned group had 100.00% of POIs scanned which was statistically significant. In the LUQ novices used 60.59s vs 41.19s, travelled a median of 2719.55mm vs 820.19mm and had a median of 40.00% vs 100.00% of POIs scanned when compared to the novice returned group. All differences in the LUQ were statistically significant. Novices used a median of 52.66s vs 47.56s and travelled 1362.56mm vs 552.70mm to complete the pericardium compared to the novice group returned. Neither time nor path length was significantly different. However the novice group had a median of 37.50% of POIs scanned vs 100.00% of the POIs scanned for the novice group returned in the pericardium, and this was statistically different. In the pelvis all differences were statistically significant. Novices used a median of 60.42s vs 32.54s, and travelled a median of 1498.42mm vs 500.61mm when compared to the novice group returned. Both the novices and the novice group returned scanned a median of 100% of the POIs, however the novice group underperformed the novice group returned. For the overall exam, the novices used more median time 290.82s vs 271.79s, a longer median path length 9392.07mm vs 4985.05mm while having a lower median proportion of POIs scanned 48.13% vs 100.00% when compared to the novice group returned. All comparisons between the novice and novice returned groups for the overall exam were statistically significant. (Table 2)

Intermediate group compared to novice returned

Finally, the intermediate and novice returned groups were not significantly different at the $p<0.05$ level in the majority of metrics in all regions. Both exceptions occurred in the RUQ where intermediate users utilized a median of 55.39s vs 121.59s of time and a lower median path length of 707.64mm vs 1739.42mm to complete the section when compared to the novices returned. Each group similarly imaged a median of 100% of POIs scanned, which was not statistically different. In the LUQ the intermediates used a median of 74.83s, 1385.97mm and imaged 100% of POIs scanned, while the returning novices used 41.19s, 820.19mm and imaged a median of 100% of POIs scanned to complete the section. For the pericardium intermediates used a median of 35.37s, 563.75mm and had 100% of the POIs scanned. Similarly the novice returned group used a median of 47.56s, 552.70mm and had 100% of POIs scanned. In the pelvis the intermediate group used a median of 26.26s, 678.45mm and had 100% of POIs scanned, while the novice returned group used a median of 32.54s, 500.61mm and had 100% of POIs scanned. When all regions were added together there was no statistical difference between the returning novice users and the intermediate group. Intermediates used a median of 197.41s, 4052.73mm and had 95.00% of POIs scanned while returned novices used 271.79s, 4985.05mm and had 100% of POIs scanned. (Table 3)

Correlations between all metrics for all groups

Spearman's correlation was generated within each group and the variables assessed. The results are displayed in table 4. Generally path length and time correlated reasonably well (rho >0.5) with each other for all groups in all regions. In the RUQ the novices, intermediates and novice returned correlations had rho values of 0.72, 0.33 and 0.93. Both the novice and novice returned values were statistically significant. For the LUQ path length and time had correlations of 0.53, 0.87 and 0.58 for the novice, intermediate and novice returned groups. Here the novice and intermediate groups were statistically significant. In the pericardium all correlations between time and path length the novice, intermediate and novice returned groups were statistically significant with values of 0.50, 0.51 and 0.78. Similarly all correlations in the pelvis were statistically significant with values of 0.85, 0.70 and 0.83 for the novice, intermediate and novice returned groups. The overall correlations between time and path length were statistically significant with values of 0.67, 0.65 and 0.90 for the novice, intermediate and novice returned groups.

For the all but one group in one segment no significant correlation was found between time and POIs scanned. The single exception occurred in the pelvis for the intermediate group where the correlation between time vs POIs scanned was statistically significant with a value of -0.59. In the pelvis the novice group had a correlation of 0.53, while no correlation could be derived for the novice returned group as all participants had 100% POIs scanned. Otherwise the RUQ correlation values of time vs POIs scanned were 0.09, -0.03 and 0.38 for the novice, intermediate and novice returned groups. In the LUQ the novice and intermediate groups had correlations of -0.07 and 0.21 while no correlation could be generated within the novice returned group because all participants had 100% of POIs scanned. For the pericardium novice, intermediate and novice returned groups had correlations of -0.01, 0.32 and 0.41. For the entire exam no statistically significant correlation was found between time and POIs scanned. The novice, intermediate and novice returned groups had rho values of -0.02, 0.22 and 0.38.

No significant correlation was found between path length and POIs scanned within any group in any region. In the RUQ the novice, intermediate and novice returned rho values were -0.26, -0.10 and 0.65. The LUQ novice, intermediate and novice returned values were -0.01, -0.22 and undefined as all novice returned participants had 100% of POIs scanned. In the pericardium the correlations between path length and POIs scanned for the novice, intermediate and novice returned groups were 0.20, 0.24 and 0.00. And in the pelvis values for the novice and intermediate groups were 0.30 and -0.29. No correlation could be generated between path length and POIs scanned for the novice returned group as all participants had 100% of POIs scanned. For the comprehensive exam no statistically significant correlation was found between path length and POIs scanned. The values for the novice, intermediate and novice returned groups were -0.27, 0.36 and 0.35. (Table 4)

Discussion

Key Results

Surgical literature indicates that experts perform physical tasks faster and with more efficient motion, and, as such, novices and more experienced users can be distinguished on the basis of their movement patterns (7-10). This study was designed to see if this principle holds true for the FAST exam, and whether probe motion and accuracy analysis might be a useful objective assessment tool for PoCUS expertise.

In our study, the intermediate group was significantly more deft and accurate in performing a FAST exam than novices in all metrics except for time and distance in the LUQ and POIs scanned in the pericardium. Although the LUQ time and distance portion was similar between the two groups, the intermediate group was much more accurate, with a median of 100% of the POIs scanned, versus the novices' 40%. In the pericardial view, the intermediate group showed a trend toward more POIs scanned in the pericardial view when compared to the novices, however it did not reach statistical significance. Since the superiority of intermediate users' motion patterns and accuracy held true over all four portions of the FAST exam, and the overall exam, it suggests that analysis of these motion patterns, along with measures of accuracy like POIs scanned, may be a valid means of assessing expertise. No significant difference was found between the intermediate and novice returned users in any section or the overall exam with the exception of the RUQ. Here the intermediate group used significantly less time and a lower path length to complete the same exam when compared to the novice returned group.

As further evidence of the utility of probe motion analysis in assessing expertise, we were able to demonstrate that after a period of practice, the disparities in time and path length between the intermediate and novice groups were greatly diminished, and that the difference in POIs scanned were eliminated in all regions and the overall exam. Interestingly, novice returned group outperformed intermediates by scanning more POIs in the complete exam but this did not reach statistical significance. The difference may be in part due to a Hawthorne or recency effect upon the novice returned group. It is unclear from this study as to whether scanning skills in more experienced users do actually decay over time.

Time and path length correlated reasonably well (rho >0.5) for all scans across the various groups, with the exception of the intermediate group in the RUQ and the novice returned group in the LUQ. We found that the number of targets hit did not correlate consistently with time or path length, meaning that these parameters alone cannot be used to measure expertise. A key component to evaluating scan completeness is measuring the number of critical anatomic structures corresponding to POIs scanned successfully. Our results suggest that novice users scan a larger area and take longer to perform the exam, but do not necessarily evaluate all the points of interest for a complete scan. This is likely due to both psychomotor skill inexperience and a lack of clarity as to what constitutes a comprehensive and thorough exam.

We believe that given the virtual nature of PoCUS, a larger percentage of POIs scanned more accurately reflects a thorough exam when compared to time or path length alone.

Currently, learners' scans are observed by an expert using a scoring system or global rating scale (3,4). The objective information provided by the Slicer IGT and Perk Tutor software may be both more accurate and more reliable than human observation. This novel POI metric shows promise for development into an automated objective method of PoCUS skill assessment.

We have designed the hardware and software setup to be accessible to other medical education centres. We have used commercially-available, inexpensive tracking hardware and completely free, open-source software. Furthermore, the hardware and software setup is flexible and may be used in multiple different skill assessment applications (5,6).

Limitations

Our study has several limitations. Firstly, a single PoCUS expert generated the POIs possibly introducing bias. Experts may not agree on exactly where, how many, and which POIs must be scanned to constitute a complete examination. However, there is good agreement amongst experts on which areas must be interrogated to constitute a complete scan (12), and the expert designating these areas had ultrasound fellowship training and extensive teaching experience. The data was collected over three separate days where the experimental construct was reassembled and recalibrated. Although the POIs for each data collection were the same, there may have been some variation that remained unaccounted for. We attempted to limit this variability by using the same live human model for each session.

This study is also limited by the small number of resident participants. In particular, six members of the novice group were unable to participate in the follow-up assessment. Due to data loss, we were unable to compare individuals within the novice group to themselves in the novice returned group, and were forced to use an unpaired statistical analysis. We observe that unpaired analysis is generally less powerful than paired analysis; however, any significant difference found would likely also be found using paired analysis (15).

Variable levels of experience were present within the intermediate cohort from operators who had just attained certification, to PoCUS users who had performed hundreds of exams. Sensitivity analyses to examine whether those intermediate participants with the most experience had superior performance on the outcome variables of interest was not undertaken due to statistical power concerns. This heterogeneous group does, however, reflect real world practice. Due to limited study resources, we were also unable to simultaneously assess participants with more traditional observation-based assessments.

Conclusion

This pilot study demonstrated that the difference in probe motion metrics between novice and proficient PoCUS users were significant and important. After training, the novice group returned and was indistinguishable from the intermediate group in the majority of variables studied. Furthermore, POIs scanned is a novel objective metric assessing the quality of a PoCUS study that does not correlate with path length, or time. Some surgical literature suggests that time can be used as a surrogate marker for expertise however this may not be the case in PoCUS. Larger studies across multiple applications will be needed to compare the POIs scanned measurement to more traditional human calculated assessments to ultimately determine its place in PoCUS training and assessment. We believe the POIs scanned metric shows promise for development into an automated objective measure of PoCUS competency and may be readily incorporated into a CBME platform.

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References

1. Ultrasound Guidelines: Emergency, Point-of-Care and Clinical Ultrasound Guidelines in Medicine. Annals of Emergency Medicine 2017;69(5):e27–e54.

2. Canadian Emergency Ultrasound Society: Core Certification. Cpocus.ca. 2017 (Accessed June 10, 2017. http://www.cpocus.ca/ceus-certifications/levels-certification/basic-ip-1-certification/)

3. Ziesmann MT, Park J, Unger BJ, Kirkpatrick AW, Vergis A, Logsetty S, et al. Validation of the quality of ultrasound imaging and competence (QUICk) score as an objective assessment tool for the FAST examination. Journal of Trauma and Acute Care Surgery 2015;78(5):1008–13.

4. Schmidt J, Kendall J, Smalley C. Competency Assessment in Senior Emergency Medicine Residents for Core Ultrasound Skills. WestJEM 2015;16(6):923–6

5. Yeo CT, Davison C, Ungi T, Holden M, Fichtinger G, McGraw R. Examination of Learning Trajectories for Simulated Lumbar Puncture Training Using Hand Motion Analysis. Academic Emergency Medicine 2015;22(10):1187–95.

6. Clinkard, D., Holden, M., Ungi, T., Messenger, D., Davison, C., Fichtinger, G. et al. (2015). The Development and Validation of Hand Motion Analysis to Evaluate Competency in Central Line Catheterization. Academic Emergency Medicine 2015;22(2):212-218.

7. Ziesmann MT, Park J, Unger BJ, Kirkpatrick AW, Vergis A, Logsetty S, et al. Validation of hand motion analysis as an objective assessment tool for the Focused Assessment with Sonography for Trauma examination. Journal of Trauma and Acute Care Surgery 2015;79(4):631–7.

8. Reiley CE, Lin HC, Yuh DD, Hager GD. Review of methods for objective surgical skill evaluation. Surg Endosc 2010;25(2):356–66.

9. Aggarwal R, Grantcharov T, Moorthy K, Milland T, Papasavas P, Dosis A, et al. An Evaluation of the Feasibility, Validity, and Reliability of Laparoscopic Skills Assessment in the Operating Room. Annals of Surgery 2007;245(6):992–9.

10. Stefanidis D, Scott DJ, Korndorffer JR Jr. Do Metrics Matter? Time Versus Motion Tracking for Performance Assessment of Proficiency-Based Laparoscopic Skills Training. Simulation in Healthcare: The Journal of the Society for Simulation in Healthcare 2009;4(2):104–8.

11. Welch M, Andrea J, Ungi T, Fichtinger G. Freehand ultrasound calibration: phantom versus tracked pointer. SPIE Medical Imaging 2013;8671:86711C–86711C–6.

12. Lewiss RE, Pearl M, Nomura JT, Baty G, Bengiamin R, Duprey K, Stone M, et al. CORD-AEUS: Consensus Document for the Emergency Ultrasound Milestone Project. Academic Emergency Medicine 2013;20(7):740–5.

13. Lasso A, Heffter T, Rankin A, Pinter C, Ungi T, Fichtinger G. PLUS: open-source toolkit for ultrasound-guided intervention systems. *IEEE Trans Biomed Eng*. 2014;61(10):2527-2537.

14. Ungi T, Sargent D, Moult E, Lasso A, Pinter C, McGraw R, et al. Perk Tutor: An Open-Source Training Platform for Ultrasound-Guided Needle Insertions. IEEE Trans Biomed Eng 2012;59(12):3475–81.

15. Keren G, Lewis C. A Handbook for data analysis in the behavorial sciences. Hillsdale, N.J.: L Erlbaum Associates; 1993.

Figure 1- Experimental Setup

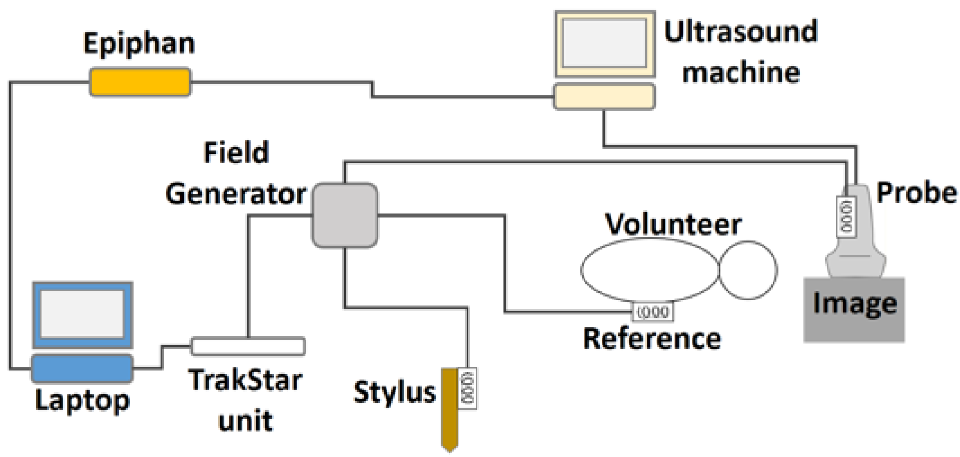

Table 1- Novice vs Intermediate comparison of time elapsed, path length and points of interest intersected

Novice			Intermediate			
	Median	Interquartile Range		Median	Interquartile Range	p Value
Right Upper Quadrant						
Elapsed Time (S)	80.65	63.27-150.61	Elapsed Time (S)	55.39	41.90- 60.42	<0.01*
Path Length (mm)	1586.10	1333.99-2464.20	Path Length (mm)	707.64	553.40-1090.91	<0.01*
POI s Scanned (%)	50.00	37.50-77.08	POI Scanned (%)	100.00	91.67-100.00	<0.01*
Left Upper Quadrant						

Elapsed Time (S)	60.59	50.00-84.96	Elapsed Time (S)	74.83	46.46-87.10	0.65
Path Length (mm)	2719.55	1305.48-3357.75	Path Length (mm)	1385.97	955.25-2360.07	0.20
POIs Scanned (%)	40.00	10.00-70.00	POIs Scanned (%)	100.00	100.00-100.00	<0.01*
Pericardium						
Elapsed Time (S)	52.66	42.72-68.70	Elapsed Time (S)	35.37	27.28-44.51	0.02*
Path Length (mm)	1362.56	662.91-2192.03	Path Length (mm)	563.75	451.63-826.40	0.03*
POIs Scanned (%)	37.50	16.67-100.00	POIs Scanned (%)	100.00	80.00-100.00	0.40
Pelvis						

Elapsed Time (S)	60.42	35.42-79.78	Elapsed Time (S)	26.26	16.99-28.41	<0.01*
Path Length (mm)	1498.42	609.84-2892.25	Path Length (mm)	678.45	439.43-835.39	0.04*
POIs Scanned (%)	100.00	25.00-100.00	POIs Scanned (%)	100.00	100.00-100.00	0.01*
Overall						
Elapsed Time (S)	290.82	210.28-391.90	Elapsed Time (S)	197.41	150.43-231.07	0.01*
Path Length (mm)	9392.07	5664.28-10911.63	Path Length (mm)	4052.73	3155.15-4712.87	0.01*
POIs Scanned (%)	48.13	29.79-79.48	POIs Scanned (%)	95.00	80.36-95.83	<0.01*

Significant results at the p<0.05 level are noted with a *

Table 2 Novice vs Novice Returned comparison of time elapsed, path length and points of interest scanned.

Novice			Novice Returned			
	Median	Interquartile Range		Median	Interquartile Range	p Value
Right Upper Quadrant						
Elapsed Time (S)	80.65	63.27-150.61	Elapsed Time (S)	121.59	75.57-144.19	0.55
Path Length (mm)	1586.10	1333.99-2464.20	Path Length (mm)	1739.42	1345.46-2611.10	0.97
POIs Scanned (%)	50.00	37.50-77.08	POIs Scanned (%)	100.00	100.00-100.00	<0.01*
Left Upper Quadrant						
Elapsed Time (S)	60.59	50.00-84.96	Elapsed Time (S)	41.19	37.62-55.34	<0.05*
Path Length(mm)	2719.55	1305.48-3357.75	Path Length (mm)	820.19	758.60-1029.70	<0.01*
POIs Scanned(%)	40.00	10.00-70.00	POIs Scanned (%)	100.00	100.00-100.00	<0.01*
Pericardium						
Elapsed Time (S)	52.66	42.72-68.70	Elapsed Time (S)	47.56	31.98-67.25	0.30

Path Length (mm)	1362.56	662.91-2192.03	Path Length (mm)	552.70	472.36-921.58	0.14
POIs Scanned (%)	37.50	16.67-100.00	POIs Scanned (%)	100.00	100.00-100.00	<0.01*
Pelvis						
Elapsed Time (S)	60.42	35.42-79.78	Elapsed Time (S)	32.54	28.73-41.73	0.03*
Path Length(mm)	1498.42	609.84-2892.25	Path Length (mm)	500.61	462.64-788.41	<0.01*
POIs Scanned (%)	100.00	25.00-100.00	POIs Scanned (%)	100.00	100.00-100.00	<0.01*
Overall						
Elapsed Time (S)	290.82	210.28-391.90	Elapsed Time (S)	271.79	174.96-319.33	0.03*
Path Length (mm)	9392.07	5664.28-10911.63	Path Length (mm)	4985.05	3402.54-6071.72	<0.01*
POIs Scanned (%)	48.13	29.79-79.48	POIs Scanned (%)	100.00	96.88-100.00	<0.01*

Results significant at the $p<0.05$ level are noted with a*

Table 3 Intermediate vs Novice Returned comparison of time elapsed, path length and points of interest scanned.

Intermediate			Novice Returned			
	Median	Interquartile Range		Median	Interquartile Range	p Value
Right Upper Quadrant						
Elapsed Time (S)	55.39	41.90- 60.42	Elapsed Time (S)	121.59	75.57-144.19	<0.01*
Path Length (mm)	707.64	553.40-1090.91	Path Length (mm)	1739.42	1345.46-2611.10	0.02*
POIs Scanned (%)	100.00	91.67-100.00	POIs Scanned (%)	100.00	100.00-100.00	0.41
Left Upper Quadrant						
Elapsed Time (S)	74.83	46.46-87.10	Elapsed Time (S)	41.19	37.62-55.34	0.06

Path Length(mm)	1385.97	955.25-2360.07	Path Length (mm)	820.19	758.60-1029.70	0.11
POI Scanned (%)	100.00	100.00-100.00	POI Scanned (%)	100.00	100.00-100.00	0.18
Pericardium						
Elapsed Time (S)	35.37	27.28-44.51	Elapsed Time (S)	47.56	31.98-67.25	0.44
Path Length (mm)	563.75	451.63-826.40	Path Length (mm)	552.70	472.36-921.58	1.00
POIs Scanned (%)	100.00	80.00-100.00	POIs Scanned (%)	100.00	100.00-100.00	0.05
Pelvis						
Elapsed Time (S)	26.26	16.99-28.41	Elapsed Time (S)	32.54	28.73-41.73	0.12
Path Length (mm)	678.45	439.43-835.39	Path Length (mm)	500.61	462.64-788.41	0.47

POIs Scanned (%)	100.00	100.00-100.00	POIs Scanned (%)	100.00	100.00-100.00	0.29
Overall						
Elapsed Time (S)	197.41	150.43-231.07	Elapsed Time (S)	271.79	174.96-319.33	0.24
Path Length (mm)	4052.73	3155.15-4712.87	Path Length (mm)	4985.05	3402.54-6071.72	0.88
POIs Scanned (%)	95.00	80.36-95.83	POIs Scanned (%)	100.00	96.88-100.00	0.09

Results significant a the p<0.05 level are noted with a *

Table 4 –Correlations of all measured values in Novice, Intermediate and Novice returned groups.

Novice			Intermediate			Novice Returned		
Spearman Correlation	Rho	p Value	Spearman Correlation	Rho	p Value	Spearman Correlation	Rho	p Value
Right Upper Quadrant								
Time vs path length	0.72	<0.01*	Time vs path length	0.33	0.12	Time vs path length	0.93	<0.01*
Time vs POIs Scanned	0.09	0.62	Time vs POIs Scanned	-0.03	0.45	Time vs POIs Scanned	0.38	0.85
Path length vs POIs Scanned	-0.26	0.19	Path length vs POIs Scanned	-0.10	0.36	Path length vs POIs Scanned	0.65	0.97

Time vs path length	0.53	0.03*	Time vs path length	0.87	<0.01*	Time vs path length	0.58	0.05
Time vs POIs Scanned	-0.07	0.40	Time vs POIs Scanned	0.21	0.77	Time vs POIs Scanned	Undefined	Undefined
Path length vs POIs Scanned	-0.01	0.49	Path length vs POIs Scanned	-0.22	0.22	Path length vs POIs Scanned	Undefined	Undefined
Pericardium								
Time vs path length	0.50	0.03*	Time vs path length	0.51	0.03*	Time vs path length	0.78	<0.01*
Time vs POIs Scanned	-0.01	0.48	Time vs POIs Scanned	0.32	0.88	Time vs POIs Scanned	0.41	0.89
Path length vs POIs Scanned	0.20	0.75	Path length vs POIs Scanned	0.24	0.81	Path length vs POIs Scanned	0.00	0.56

Pelvis								
Time vs path length	0.85	<0.01*	Time vs path length	0.70	<0.01*	Time vs path length	0.83	<0.01*
Time vs POIs Scanned	0.53	0.97	Time vs POIs Scanned	-0.59	0.01*	Time vs POIs Scanned	Undefined	Undefined
Path length vs POIs Scanned	0.30	0.85	Path length vs POIs Scanned	-0.29	0.15	Path length vs POIs Scanned	Undefined	Undefined
Overall								
Time vs path length	0.67	<0.01*	Time vs path length	0.65	<0.01*	Time vs path length	0.90	<0.01*
Time vs POIs Scanned	-0.02	0.47	Time vs POIs Scanned	0.22	0.79	Time vs POIs Scanned	0.38	0.85

Path length vs POIs Scanned	-0.27	0.17	Path length vs POIs Scanned	0.36	0.91	Path length vs POIs Scanned	0.35	0.83

Results significant at the p<0.05 level are noted with a *