ORIGINAL RESEARCH

Does Point-of-Care Ultrasound Change the Needle Insertion Location During Routine Bedside Paracentesis?

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BACKGROUND: Paracentesis is a bedside procedure to obtain ascitic fluid from the peritoneum. Point-of-care ultrasound (POCUS) improves the safety of some medical procedures. However, the evidence supporting its utility in paracentesis is limited.

OBJECTIVE: We aimed to assess if POCUS would yield a user-preferred site for needle insertion compared to conventional landmarking, defined as a ≥ 5 cm change in location.

DESIGN: This was a prospective non-randomized trial comparing a POCUS-guided site to the conventional anatomic site in the same patient.

PARTICIPANTS: Adult patients at Kingston Health Sciences Centre undergoing paracentesis were included.

INTERVENTIONS: Physicians landmarked using conventional technique and compared this to a POCUS-guided site. The paracentesis was performed at whatever site was deemed optimal, if safe to do so.

MAIN MEASURES: Data collected included the distance from the two sites, depth of fluid pockets, and anatomic considerations.

KEY RESULTS: Forty-five procedures were performed among 30 patients and by 24 physicians, who were primarily in their PGY 1 and 2 years of training (33% and 31% respectively). Patients' ascites was mostly due to cirrhosis (84%) predominantly due to alcohol (47%) and NAFLD (34%). Users preferred the POCUS-guided site which resulted in a change in needle insertion ≥ 5 cm from the conventional anatomic site in 69% of cases. The average depth of fluid was greater at the POCUS site vs. the anatomic site (5.4±2.8 cm vs. 3.0±2.5 cm, $p < 0.005$). POCUS deflected the needle insertion site superiorly and laterally to the anatomic site. The POCUS site was chosen (1) to avoid adjacent organs, (2) to optimize the fluid pocket, and (3) due to abdominal wall considerations, such as pannus. Six cases landmarked anatomically were aborted when POCUS revealed inadequate ascites.

CONCLUSIONS: POCUS changes the needle insertion site from the conventional anatomic site for most procedures, due to optimizing the fluid pocket and safety concerns, and helped avoid cases where an unsafe volume of ascites was present.

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Abbreviations

ASIS	Anterior superior ileac spine
GI	Gastroenterology
GIM	General internal medicine
IQR	Interquartile range
NAFLD	Non-alcoholic fatty liver disease
PGY	Post-graduate year
POCUS	Point-of-care ultrasound

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INTRODUCTION

Paracentesis is a procedure in which a needle is inserted into a patient's peritoneum to obtain ascitic fluid, either for diagnostic or therapeutic purposes. Historically, the method for performing this bedside procedure utilizes physical exam and anatomic landmarking to select a safe site to insert the needle. The most common approaches are superomedially to the anterior superior iliac spine (ASIS) or sub-umbilical[1]. Serious complications from this procedure (including sepsis, hemorrhage, and perforation) are rare, and occur in less than 2% of cases.[2] However, numerous factors can increase the complication rate such as small volume ascites and diagnostic-only procedures.[2] In addition, non-alcoholic fatty liver disease (NAFLD) is becoming the most prevalent cause of cirrhosis[3] and anatomic landmarking can be challenging in patients with obesity.[4]

Point-of-care ultrasound (POCUS) technology has developed rapidly as a bedside aide to improve safety of procedures. In the 1990s, the use of POCUS was shown to decrease rates of arterial puncture during central line insertion by more than half.[5] In addition, thoracentesis with ultrasound guidance is associated with lower rates of pneumothorax.[6] These and other studies have made POCUS a valuable tool for physicians and is included in training programs at the medical school and residency levels. Many medical programs have integrated POCUS teaching into their medical school[7] and residency curriculum.[8]

Despite its widespread acceptance, the literature describing the safety benefit of ultrasound in paracentesis is limited.[6,9–12] To date, there is no randomized controlled trial assessing

POCUS vs. conventional anatomic landmarking and percussion for safety and efficacy of bedside paracentesis. This may be because paracentesis is safe in most circumstances and the number of patients required to show a safety difference, if any, would be exceedingly large. Nonetheless, evidence should be present to inform decisions around adopting POCUS for paracentesis in medical curriculum and clinical practice.

In this practical clinical trial, we aimed to assess if the use of POCUS yielded a preferred location for needle insertion compared to conventional anatomic landmarking, measured by user-perceived safety, depth of fluid pocket, proximity to nearby organs, or other anatomic considerations.

METHODS

Study Design

This was a non-randomized clinical trial using pairwise comparisons in individual patients to compare POCUS to anatomic landmarking. The main objective was to determine if POCUS yielded a user-preferred needle insertion site.

Study Population

Patients ≥ 18 years of age undergoing bedside paracentesis at the Kingston Health Sciences Center (KHSC) between January and September of 2020 were included. KHSC is an acute care academic hospital in Ontario, Canada, affiliated with the Queen's University School of Medicine, and an accredited training site for several residency programs including family medicine, general internal medicine (GIM), and gastroenterology (GI). Both admitted patients and outpatients were included. Prior to enrollment, patients were required to have radiographically identified ascites (not including POCUS) or clinically suspected ascites (based on the presence of pedal edema and at least one of the following: shifting dullness, fluid wave, or flank dullness. Patients were excluded if they had known loculated ascites, hemodynamic instability, suspected bowel obstruction, pregnancy, abdominal wall cellulitis, or a platelet count < 20×10^9/L. Residents (post-graduate years 1–5), clinical fellows, and attending physicians on the internal medicine or gastroenterology service were included to perform paracenteses. Patients and physicians could be enrolled in the study on more than one occasion; however, only unique combinations of a physician and patient were included.

Procedure

Physicians first performed anatomic landmarking by locating the anterior superior iliac spine and moving superiorly 4 cm and medially 2–4 cm and confirming dullness by percussion.[1] If the area was not dull, the surrounding area would be percussed laterally and superiorly until a dull spot was obtained. After marking this area, the physician would then utilize POCUS to determine if there was an alternative, more optimal site for paracentesis. The physician would then use the POCUS to characterize the anatomically selected site. Data would then be recorded by the physician or an observer/supervisor including depth of fluid pocket, distance from POCUS-guided site to anatomic site, patient demographics, physician characteristics, and other procedure-related information. A threshold of 10 paracenteses was set to discriminate between novice and experienced individuals based on procedural competency research by Grabau et al.[13] For novice performers and if supervision was requested, senior residents or attending physicians were present but only provided specific guidance if asked. Additionally, physicians were asked to sketch the POCUS and anatomic sites on a graphic representation of an abdomen.

Outcomes

The primary outcome was whether POCUS yielded a change in needle insertion site of ≥ 5 cm from the anatomic site. Secondary outcomes included whether procedures were aborted due to findings on POCUS, depth of fluid pocket, distance between the anatomic and POCUS sites, and the reasons for which one site was chosen over another (i.e., abdominal wall considerations, nearby organs, optimizing fluid pocket).

Statistical Analysis

The mean difference between pairs was estimated to be 2 cm, with a standard deviation of 3 cm. Using these parameters, the study would require a minimum of 22 pairs to achieve a power of 80% using an alpha of 0.05. However, variability in physician training level, variety of clinical settings, and patients would all increase the variability. We therefore conservatively doubled this to 45 procedures, to demonstrate that POCUS would change the site of paracentesis by at least 5 cm 20% of the time. Descriptive statistics were used to discuss most of the findings.

The distance between the POCUS and anatomic sites was measured with a tape ruler and physicians then drew the relative locations of these sites on a graphic representation of an abdomen. To determine the X- and Y-deflection of the POCUS from the anatomic site, X- and Y-components were calculated using the approximated angle of deflection from the anatomic site to the POCUS site and the distance between the two sites with sin/cosine functions.

Student's *t* tests were used when comparing the means of two samples. Error was listed as standard deviation of the mean or interquartile ranges between the 1st and 3rd quartiles if mean or median values were listed, respectively.

Ethics

Consent was obtained from all patients and physicians participating in the study. This study was approved by the Health

Table 1 Physician Characteristics, per Paracentesis Procedure

Training	
PGY 1	15 (33%)
PGY 2	14 (31%)
PGY 3	1 (2%)
PGY 4	4 (9%)
PGY 5	9 (20%)
Attending physician	2 (4%)
Training program	
Internal medicine	30 (67%)
Gastroenterology	11 (24%)
Other	4 (9%)
Prior paracentesis with POCUS	
< 10	26 (58%)
≥ 10	19 (42%)
Prior experience of paracentesis without use of POCUS (y)	17 (38%)

Sciences Research Ethics Board at Queen's University. This study was registered on clinicaltrials.gov (NCT04245553).

RESULTS

Physician Characteristics

In total, 24 physicians were recruited to perform 45 paracenteses (Table 1), with a median of 1 procedure per physician (IQR 1,1) and a maximum number of 6 procedures for any one physician. Most procedures were performed by first- and second-year residents, and physicians were primarily internal medicine residents. Fifty-eight percent of physicians had performed less than 10 paracenteses in their career thus far, and 38% had performed a paracentesis without the use of POCUS. All had received a combination of experiential and formal teaching in POCUS throughout their medical school and/or residency training.

Table 2 Patient Characteristics, per Paracentesis Procedure

Total patients	30
Paracenteses per patient (median, IQR)	1 (IQR 1,1); max number per patient = 5
Age (mean, SD)	61 (± 9)
Sex (F)	16 (36%)
Outpatients	11 (24%)
Etiology of ascites per procedure	
Cirrhosis	38 (84%)
Malignancy	4 (9%)
Cardiac	1 (2%)
Other	2 (4%)
Cause of cirrhosis	
Alcohol	18 (47%)
NAFLD	13 (34%)
Hepatitis C	3 (8%)
Alcohol and hepatitis C	2 (5%)
Other	2 (5%)
Indication for procedure	
Therapeutic	24 (53%)
Diagnostic	13 (29%)
Both	8 (18%)
Suspicion of ascites prior to enrollment	
Clinical exam alone	6 (13%)
Radiologic findings alone	5 (11%)
Both	34 (76%)

Patient Characteristics

In total, 30 patients were recruited and participated in the 45 paracenteses (Table 2), with a median of 1 procedure per patient (IQR 1,1) and a maximum of 5 procedures for any one patient. Per procedure, the mean age of patients was 61 years old (±9) and 64% were males. The etiology of ascites was cirrhosis in 84% of the procedures, and cirrhosis was most commonly caused by alcohol use alone (47% of cirrhosis cases) and NAFLD (34% of cirrhosis cases).

The procedures were performed predominantly for therapeutic purposes (53%) whereas 18% were for both diagnosis and therapy, and 29% were for diagnostic purposes alone. The presence of ascites had to be suspected by radiologic findings (not including POCUS) and/or clinical exam prior to enrollment. Most cases had both a supportive bedside clinical exam and prior radiologic evidence of ascites (76%) whereas 13% had clinical suspicion alone with no contemporaneous radiologic imaging and 11% had radiologic findings alone with no clear bedside evidence.

Paracentesis Characteristics

Overall, of 45 cases, POCUS resulted in 6 (13%) procedures being aborted due to unsafe volume of ascites; of the remaining 39 procedures, POCUS resulted in a change of position of ≥ 5 cm in 32 procedures. Of the 39 procedures, 38 were done at the POCUS site. Physicians reported a preference for the POCUS site in 85% (33/39) of procedures, no preference in 12.5% (5/39) of procedures, and anatomic site preference for 1 of the 39 cases (2.6%). All cases which physicians reported no preference were performed at the POCUS site for undisclosed reasons. Of the 32 cases which result in a change of position of ≥ 5 cm, 28 were from the POCUS site preferred group, and 4 were from the no-preference group.

Physicians listed a variety of reasons for which the POCUS site was chosen including optimizing the size of the fluid pocket in 24 of the cases (61%), abdominal wall

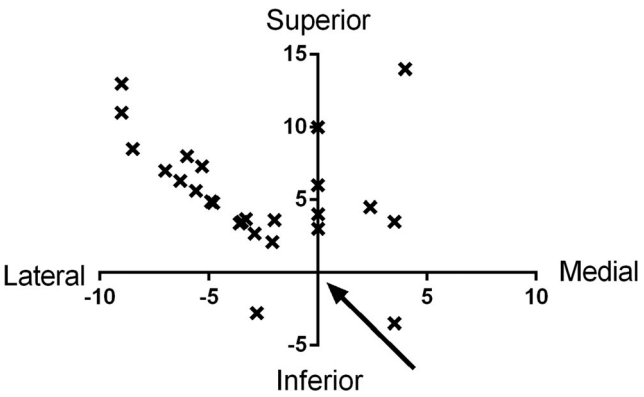

Figure 1 Schematic depicting the POCUS-guided needle puncture sites in relation to the conventional anatomic site, located at *x*, *y* = 0cm (arrow). The *y*-axis is oriented vertically along the patient's midline (sagittal) with positive deflection being superior (cephalad), whereas the *x*-axis lies horizontally (transverse) with positive deflections being medial.

considerations in 10 cases (23%; of which half were due to excess adipose tissue at the anatomic site), or the presence of adjacent organs or vascular structures in 15 cases (38%). Physicians believed that the original anatomic site was unsafe in 58% of the procedures.

On average, the POCUS-directed paracentesis site had significantly deeper ascites than the anatomic site (5.4 cm ± 2.8 cm vs 3.0 cm ± 2.5 cm, $p < 0.005$). With regard to location, the POCUS site was an average of 8.3 cm ± 4.7 cm from the anatomic site. The POCUS site was on average superior (5.4 cm ± 4.1 cm) and lateral (2.9 cm ± 3.9 cm) to the anatomic site (Fig. 1).

Failed and Aborted Cases

Six paracenteses out 45 cases (13%) were aborted due to a lack of a safe fluid pocket identified by POCUS that would have otherwise been performed. Four of these were diagnostic procedures, and two were for therapeutic purposes. In one case, only clinical suspicion of ascites was present prior to the procedure whereas the others had recent abdominal imaging of ascites in addition to clinical suspicion.

One case was unsuccessful despite POCUS identifying a sufficient volume of ascites due to the lack of a needle long enough to traverse the patient's overlying pannus.

DISCUSSION

The use of POCUS is widespread in performing medical procedures such as thoracentesis and central line insertion.[5,6] Its role in assisting with paracentesis is less developed given a lack of clear efficacy data. In this real-world study, we show that POCUS can play an important role in this procedure and adds to the growing literature base that supports its use in paracentesis.[6,9–12]

In the present study, physicians preferred the site obtained by POCUS when performing paracentesis. This was due to the ability to optimize the size of a fluid pocket, minimize adjacent organs, and navigate around abdominal wall issues such as scarring, infection, or adipose tissue. But perhaps more importantly, not only did POCUS yield a user-preferred paracentesis site; it also appears to have significant safety implications. A total of six procedures (13% of total procedures) where bedside paracentesis would have normally been performed were aborted because of information garnered from the use of POCUS. These procedures had an unsafe (or no appreciable) volume of fluid to drain despite bedside exam and/or previous radiologic confirmation of ascites and could have resulted in failed procedures or, worse yet, damage to abdominal organs. Therefore, POCUS had an important role in assessing for ascites prior to bedside paracentesis.

The data regarding safety benefits for POCUS in thoracentesis and central line insertion has been well studied. However, evidence regarding the benefit of POCUS in paracentesis is less robust. Most studies have been large retrospective studies or health database studies that have showed mixed results regarding complication rates between POCUS and conventional paracentesis.[6,9,12] Furthermore, only one clinical trial to our knowledge has been designed to compare POCUS to conventional paracentesis in the emergency room setting, which suggested that ultrasound leads to an overall increase in success of the procedure but the study lacked important information regarding patient data.[10] Despite a relative paucity of data in this field, as remarked on by other groups,[14] medical school and residency curriculum across North America have begun to adopt POCUS for this procedure.[7,8] This is made particularly evident by the low number of participants in our study that have performed paracentesis without the use of POCUS. Our study adds to the justification of using POCUS for routine paracentesis and teaching POCUS landmarking within a medical school and residency curriculum.

The face of cirrhosis has evolved significantly in the past two decades. Whereas cirrhosis was commonly believed to be a disease of older men in the north American population due to hepatitis or EtOH use, new evidence suggests that the prevalence is increasing in young cohorts of patients,[15] and that NAFLD is becoming a predominant cause of cirrhosis.[16] This is reflected in our study, where one-third of patients with cirrhosis and ascites had underlying NAFLD. Given the changing etiology of cirrhosis and prevalence of obesity in patients with end-stage liver disease,[17] the safety of a "blind" (i.e., conventional anatomic) paracentesis comes into question. POCUS theoretically has the ability to find areas on the abdominal wall where adipose tissue is not a significant barrier to the procedure, as well as to search for optimal fluid pockets that may have been redistributed due to increased intraabdominal pressures.[18] It was therefore no surprise that pannus was commonly listed as a reason for preferring the POCUS-guided paracentesis site.

There exists a theoretical risk that, in search of an optimal pocket of fluid, a physician will select a needle insertion site that is paradoxically unsafe, i.e., close to midline structures such as bladder or the inferior epigastric artery, both of which can be missed or misinterpreted by a novice POCUS user. During the procedure, we asked physicians to mark down the sites of the anatomic and POCUS needle insertion on a diagram of the abdominal wall. These drawings suggested that POCUS most often deflects the needle insertion superiorly and laterally to the anatomic site. This is suspected to be a safer area as it is further from the vital midline structures mentioned above. Furthermore, POCUS users can learn to use Doppler to identify and avoid abdominal wall vasculature and further improve the safety of the procedure.

There are limitations to our study. It was not a randomized controlled trial. Instead, we chose a study using pairwise comparisons on the same patient, which has its strengths and limitations. This allowed us to compare two sites on the same patient and provided unique insights as to how POCUS changes conventional management in any given patient. In addition,

the primary endpoint was whether POCUS yielded a user-preferred paracentesis site and not whether POCUS prevented complications of the procedure. Our primary endpoint and study design were selected because the rate of major complications of paracentesis is low (< 2%).[2] To show a significant difference between POCUS and anatomic landmarking in complications, a RCT would be required, with a very large number of patients enrolled, which was not feasible within our center. Nonetheless, POCUS helped avoid six procedures with no drainable ascites and resulted in overall safer procedure sites as per the physician performing the procedure.

In conclusion, using POCUS to landmark for paracentesis identified a preferred location compared to conventional anatomic landmarking. The POCUS site was preferred for patient safety concerns and procedure optimization. More importantly, POCUS averted procedures where negligible ascites was present and that could have resulted in complications. This study demonstrates the safety implications of POCUS in bedside paracentesis and supports its continued use in clinical care and incorporation into medical education.

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Declarations:

Conflict of Interest: *The authors declare that they do not have a conflict of interest.*

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