Intravenous Fluid Bag as a Substitute for Gel Standoff Pad in Musculoskeletal Point-of-care Ultrasound

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ABSTRACT

Introduction:

Point-of-care ultrasound (POCUS) is a tool undergoing expanding use in military medicine, including routine inpatient, outpatient, and operational environments. Specific musculoskeletal POCUS examinations require additional equipment in the form of a standoff assist device to maximize image acquisition. These devices may not be readily available to POCUS users in more austere or resource-constrained environments. We devised a study to determine if intravenous fluid bags of various volumes could be substituted for standard standoff devices in musculoskeletal POCUS.

Materials and Methods:

Sequential images of a soft tissue foreign body model, an interphalangeal joint, and a chest wall were taken using a gel standoff pad or water bath and compared to images acquired using three different sizes of intravenous fluid bags after removing excess air from the bags. Images were de-identified and scored for quality using a visual analog scale. We used a two-factor analysis of variance without replication to analyze the differences in image quality between standoff devices, with a $P$-value less than .05 considered statistically significant.

Results:

We performed 13 POCUS studies and had a group of eight POCUS-trained physicians and physician assistants score these studies, resulting in 104 total quality scores. There was no significant difference in image quality between standoff devices for chest ($P$-value .280) and hand ($P$-value 0.947) images. We found a significant difference in image quality between standoff devices for the soft tissue foreign body model ($P$-value 0.039), favoring larger intravenous fluid bag standoff over standard devices.

Conclusions:

In the absence of a standard commercial gel standoff device or water bath, intravenous fluid bags of 50, 100, and 250 mL can facilitate quality image acquisition for musculoskeletal POCUS.

INTRODUCTION

Point-of-care ultrasound (POCUS) is a reliable diagnostic tool with use expanding outside of the traditional emergency department setting, including inpatient and outpatient areas and resource-constrained environments. As technology advances with the introduction of highly portable, handheld transducers, which can attach to tablets and smartphones, POCUS is moving into areas that may have logistical limitations. POCUS examinations such as extended focused assessment with sonography for trauma, musculoskeletal POCUS (MSK-POCUS), and altitude-related evaluations such as lung POCUS for high-altitude pulmonary edema enhance the care provided in austere environments. The U.S. Army medics are now routinely trained to perform trauma-based POCUS examinations at, or very close to, the point of injury. In a military or resource-constrained environment, MSK-POCUS carries significant importance. During one 15-month deployment to Iraq, a review of the disease and non-battle injuries within a brigade combat team resulted in 1,324 musculoskeletal injuries. Examples of MSK-POCUS examinations with documented pathologic findings include shoulder dislocations, tendon injuries, both laceration and rupture, long bone fractures, ligament injuries, joint effusions, and joint pain. The MSK-POCUS adds significant diagnostic capabilities to trained healthcare providers and can influence medical decision-making, including the critical determination of whether or not to evacuate an injured patient.

The MSK-POCUS of particular body parts requires a standoff assist device, in addition to a gel interface, to optimize the focal length of the transducer and thereby facilitate a clear image of the target structure. The most common standoff devices are a reusable 2.5 centimeter thick gel pad, applied over a thin layer of gel or a water bath of sufficient depth to submerge the pertinent body part. A gel pad’s advantage over a water bath or a thick application of acoustic gel lies with its ability to stabilize the transducer against a semi-solid surface and allow for a consistent depth of scanning.
Resource-constrained environments often lack extra assistive POCUS equipment outside of acoustic ultrasound gel. Even gel may be difficult to come by given the expense, transport, and quantity required. Research into substitutes has demonstrated adequate reconstitutable media that could replace gel, such as glucomannan, a commercially available supplement, mixed with water. When compared to commercial ultrasound gel, it provided comparable image quality with slightly lower diagnostic adequacy. Intravenous fluid (IVF) bags are readily available in nearly any clinic, inpatient area, or field bag. Their use for this purpose may help reduce the logistical burden associated with care in resource-restricted areas. We designed a proof-of-concept study to determine if an IVF bag could serve as an adequate substitute in MSK-POCUS, where a gel standoff pad would generally be required.

METHODS
We performed sequential imaging of a Blue Phantom soft tissue foreign body (STFB) model, a third proximal interphalangeal (PIP) joint (hand), and the right upper chest wall (chest) of one of the authors, using a GE Venue2 portable ultrasound with a 12-MHz linear transducer. The Blue Phantom models are well known in POCUS simulation exercises for training STFB identification and needle-to-target procedures. Images were obtained by POCUS fellowship-trained physicians, using a CivcoTM 1 by 10 cm × 15 cm rectangular Acoustic Standoff Pad and three different sizes of IVF bags: 50 mL, 100 mL, and 250 mL. We selected these sizes based on the bag’s overall size compared to a gel standoff pad and their representation of the most commonly stocked IVF bags in medics’ aid bags and resuscitation kits. In addition to the IVF bags, we imaged the hand using a water bath, a standard approach in hand/foot POCUS. The water bath was prepared using a large plastic bin, filled with tap water to a level that completely submerged the author’s hand with at least 1 inch of water space between the dorsal surface of the hand and the transducer face. The IVF bags were prepared by inserting a needle into the port to remove excess air to avoid a plastic–air–fluid interface in the scanning space.

Each image received an ultrasound machine-generated automated ID number, entered into a key that the primary investigator kept. We captured each standoff device and target combination image set as a unique study to facilitate blinded image review. During image acquisition, the sonographer applied 5 mL of standard ultrasound gel (Aquasonic 100 Ultrasound Transmission Gel) to the surface to be examined. Each standoff device was placed over the applied gel, and an additional 5 mL of gel was applied to the top surface of the standoff device. The sonographer utilized the high-resolution setting, equivalent to a frequency of 11 MHz, for the linear transducer. Gain optimization occurred for the first image obtained with the gel standoff pad or water bath, with gain level left in place for subsequent images with other standoff devices on that body part or model. The sonographer adjusted the depth, as needed, to achieve an ideal view of the target structure with each image. Four images were taken for each study: transverse and sagittal views, both cine and still, with still images focused on the target area. (Fig. 1).

Physicians and physician assistants with variable experiences in POCUS, ranging from novice to expert, reviewed each set of images for quality assessment. Randomization and de-identification of standoff device occurred before image presentation for quality assessment, with images grouped into a hand–Phantom–chest wall sequence. Reviewers were asked to answer the question: “Can I see the intended target structures enough to deem the study adequate for decision making?” and then were asked to select the quality of all four images in the individual study by marking an “X” on a visual analog scale (VAS). Both cine and still images in each orientation were reviewed, and the VAS was scored on the total impression of all four study images. The VAS was 10 cm in length, with the far left of the scale representing “image too poor to interpret” and the far right of the scale representing “best image I’ve ever seen of this target area.” The VAS for each study was collected, measured, and recorded on the master key.

Data were analyzed using Microsoft Excel 2016. A two-factor analysis of variance without replication was used to analyze the difference between image quality and standoff devices with a P-value less than .05 considered statistically significant. 95% Confidence intervals were calculated for all means for each standoff device.

RESULTS
Thirteen POCUS studies with four images each were performed, and all 13 studies were scored by eight physicians and physician assistants trained in POCUS, resulting in 104 total quality scores. All studies were marked “Yes” by all reviewers (N = 104, 100%) with respect to the ability to see target structures with enough clarity to allow adequate decision-making. The mean (95% CI) image quality measured on the VAS for each standoff device were gel pad 6.83 (6.12, 7.54), 50-mL bag 7.15 (6.54, 7.76), 100-mL bag 7.18 (6.45, 7.91), 250-mL bag 7.03 (6.25, 7.80), and water bath 7.31 (6.00, 7.31). There was no significant difference in image quality for individual body parts between standoff devices for chest (P-value .280) and hand (P-value .947). There was a significant difference in image quality between standoff devices for the STFB (P-value .039), with the image quality from the 100 mL and 250 mL assigned higher VAS scores (7.2, 7.2) over those images created with the gel pad and 50-mL bag (5.8, 6.5) (Table I).

DISCUSSION
As the use of POCUS moves further into austere environments, aided by portable probes, artificial intelligence programming, and reconstitutable gel substitutes, the ability of POCUS to aid clinical decision-making is nearly limitless. When entertaining new technology movement from the
FIGURE 1. Traditional standoff device and intravenous fluid (IVF) bag standoff images: Panels A and D are still images of the soft tissue foreign body (STFB) model taken with a gel pad (A) and with a 250-mL IVF bag (D). A linear foreign body is clearly visible in both images. Panels B and E are still images of the hand taken with a water bath (B) and a 100-mL IVF bag E, with the third proximal interphalangeal (PIP) joint, joint space, and extensor tendon clearly visible. Panels C and F are still images of the chest taken with a gel pad (C) and a 100-mL IVF bag (F) on the anterior chest wall. Rib shadows, pleura, and a normal artifactual A line are clearly visible. All images were obtained with a 12-MHZ linear transducer. The chest image was also captured without the tissue harmonics setting engaged.

TABLE I. Mean Scores from the Visual Analog Scale (VAS)

<table>
<thead>
<tr>
<th>VAS mean scores</th>
<th>Water bath</th>
<th>Gel Stand-off pad</th>
<th>50-mL IVF bag</th>
<th>100-mL IVF bag</th>
<th>250-mL IVF bag</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Phantom/STFB (N)</td>
<td>N/A</td>
<td>5.8 (8)</td>
<td>6.5 (8)</td>
<td>7.2 (8)</td>
<td>7.2 (8)</td>
<td>.039</td>
</tr>
<tr>
<td>Third PIP joint (N)</td>
<td>7.7 (8)</td>
<td>7.4 (8)</td>
<td>7.5 (8)</td>
<td>7.8 (8)</td>
<td>7.6 (8)</td>
<td>.95</td>
</tr>
<tr>
<td>Chest wall (N)</td>
<td>N/A</td>
<td>7.3 (8)</td>
<td>7.5 (8)</td>
<td>6.6 (8)</td>
<td>6.2 (8)</td>
<td>.28</td>
</tr>
</tbody>
</table>

Mean scores from the VAS by body part/examination and individual standoff device. Only the third PIP joint was examined with a water bath. Abbreviations: IVF, intravenous fluid; STFB, soft tissue foreign body; PIP, proximal interphalangeal.

hospital to the field, or from a resource-intense area like an emergency room to a resource-modest area like a clinic or aid station, that technology should have as few additional resource limitations as possible.

Musculoskeletal injuries are exceedingly common in deployed and garrison environments. Standoff devices are necessary to perform some MSK-POCUS to obtain appropriate image quality for adequate decision-making. We sought to improve the ability to capture quality images without needing extra equipment.

The IVF bags are readily available, reusable, and provide an ideal medium for the transmission of sound waves. We found them to serve as an adequate substitute for off-the-shelf standoff pads. The IVF bags are cost-effective compared to commercially produced gel standoff pads, $1.32 versus $8.35, when procured through usual military supply systems.

Although the study was performed using a sophisticated portable ultrasound system, the parameters used for scanning and acquiring the images are achievable on all basic portable ultrasound systems, including handheld smart device ultrasound probes currently on the market. Thus, our findings are generalizable to any POCUS practitioner with an ultrasound.

The IVF bags of all three sizes had comparable quality scoring on the VAS with the standard gel pad and the water bath.

While there was a statistical difference in quality for the Soft Tissue Foreign Body model images, the difference favored the larger-sized IVF bags. We hypothesize that the larger fluid bags provided additional standoff space to optimize focal length, given the foreign body’s depth seated within the model’s medium.
As this was a simple proof-of-concept study, it was not powered to demonstrate non-inferiority. Given the lack of statistical significance between the different devices on real human tissue, it is reasonable to conclude that musculoskeletal POCUS performed with an IVF bag can produce images of reasonable quality and interpretable by a range of POCUS providers.

We recommend additional studies to validate the use of IVF bags as a substitute for formal gel standoff pads when performing MSK or soft-tissue POCUS. Additional avenues of research could include MSK or soft-tissue POCUS performance with IVF bag standoff by U.S. Army Medics trained in POCUS, performance of IVF bag standoff to evaluate defined injury patterns to identify diagnostic differences between standoff pads and IVF bags, and exploration of additional soft tissue injury targets where IVF bags may serve as an adequate adjunct to diagnostic or therapeutic POCUS.

CONCLUSION
This project successfully demonstrates the feasibility of utilizing a readily available and reusable resource—an IVF bag—to substitute for a formal gel standoff pad when performing MSK or soft-tissue POCUS, making MSK-POCUS more readily available and interpretable in resource-constrained environments.

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CONFLICT OF INTEREST STATEMENT
None declared.

REFERENCES