Original Article

Use of point-of-care ultrasound for the assessment of intravascular volume in five rural New Zealand hospitals

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This article has been peer reviewed.

Access this article online

Quick Response Code:

Website: www.cjrm.ca

DOI: 10.4103/CJRM.CJRM_26_18

Abstract

Introduction: Measuring the diameter of the inferior vena cava (IVC) or the height of the jugular venous pressure (JVP) with point-of-care ultrasound (POCUS) is a practical alternative method for estimating a patient's intravascular volume in the rural setting. This study aims to determine whether or not POCUS of the IVC or JVP generates additional useful clinical information over and above routine physical examination in this context.

Methods: Twenty generalist physicians, working in five New Zealand rural hospitals, recorded their estimation of a patient's intravascular volume based on physical examination and then again after performing POCUS of the IVC or JVP, using a visual scale from 1 to 11.

Results: Data were available for 150 assessments. There was an only moderate agreement between the pre- and post-test findings (Spearman's correlation coefficient = 0.46). In 28% (42/150) of cases, the difference was four or more points on the scale, and therefore, had the potential to be clinically significant.

Conclusion: In the rural context, POCUS provides new information that frequently alters the clinician's estimation of a patient's intravascular volume.

Keywords: Inferior vena cava, point-of-care, rural, ultrasound, volume assessment

Résumé

Introduction: La mesure du diamètre de la veine cave inférieure ou de la hauteur de la pression veineuse jugulaire à l'aide de l'échographie au point de service est une méthode pratique pour estimer le volume intravasculaire d'un patient en région rurale. Cette étude vise à déterminer si oui ou non l'échographie au point de service de la veine cave inférieure ou de la pression veineuse jugulaire génère un surcroît d'information clinique utile par rapport à l'examen physique de routine dans ce contexte.

Méthodologie: Vingt médecins généralistes de 5 hôpitaux des régions rurales de la Nouvelle-Zélande ont noté sur une échelle visuelle de 1 à 11 leur estimation du volume intravasculaire des patients basée sur l'examen physique, puis après une échographie au point de service de la veine cave inférieure ou de la pression veineuse jugulaire.

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How to cite this article: Nixon G, Blattner K, Finnie W, Lawrenson R, Kerse N. Use of point-of-care ultrasound for the assessment of intravascular volume in five rural New Zealand hospitals. Can J Rural Med 2019;24:109-14.

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Résultats: Des données se rapportant à 150 évaluations étaient disponibles. La concordance entre les résultats d'avant le test et d'après le test n'était que modérée (coefficient de corrélation de Spearman = 0,46). Dans 28 % (42/150) des cas, la différence était de quatre points ou plus sur l'échelle et avait donc le potentiel d'être cliniquement significative.

Conclusion: En contexte rural, l'échographie au point de service fournit de nouveaux renseignements qui altèrent fréquemment l'estimation du volume intravasculaire par le clinicien.

Mots-clés: Échographie, évaluation du volume, point de service, rural, veine cave inférieure

INTRODUCTION

An ability to estimate the intravascular volume in patients with heart failure, dehydration, or shock is an important skill. Clinical estimation of intravascular volume by physical examination of the jugular venous pressure (JVP) is, however, often inaccurate.[1-3] Estimates of the failure to accurately visualise the JVP by physical examination range from 10% to 80%.[4,5] The alternative is central venous pressure (CVP) monitoring, which is invasive and impractical in many clinical contexts. Point-of-care ultrasound (POCUS) is now emerging as a further, and practical, option for intravascular volume assessment.[6,7] POCUS techniques for intravascular volume assessment include: (i) measuring the diameter and collapsibility of the inferior vena cava (POCUS-IVC) or (ii) the height of the JVP (POCUS-JVP).[4,6]

Studies undertaken in emergency medicine and specialist outpatient settings suggest that POCUS is more accurate than physical examination. In a study of cardiology clinic patients, the discordance between POCUS-IVC and JVP by physical examination was 32%, with POCUS proving more accurate.[8] In another study, physical examination of the JVP by medical students had a sensitivity of only 13%, rising to 86% when undertaken by experienced cardiologists, the same sensitivity the medical students achieved with POCUS-IVC after a brief POCUS training session.[2]

Despite being more accurate than physical examination, the ability of POCUS-IVC to predict CVP and fluid responsiveness remains controversial. One systematic review of 21 studies concluded that POCUS-IVC measurement was a 'valid method of estimating CVP' and given its 'ease and safety' recommended its 'broader adoption'.[6] A second review of 17 studies concluded that respiratory variation of IVC diameter has limited ability to predict fluid responsiveness (pooled sensitivity = 0.63 and specificity = 0.73).[7]

The value of POCUS has been more clearly demonstrated in particular clinical situations. POCUS-IVC is a good predictor of fluid responsiveness when the measurements are either very low or very high,[9,10] when the primary problem is volume loss (dehydration or blood loss) and when it is combined with other POCUS examinations (lung and cardiac).[10] POCUS-IVC has a proven role in heart failure, identifying (in combination POCUS of the lungs and heart) heart failure as the cause of acute breathlessness[5,11] and as an independent predictor of heart failure prognosis (comparable to brain natriuretic peptide).[12] It is, however, still unknown if using POCUS-IVC to guide treatment improves outcomes for heart failure patients.

Rural physicians are increasingly incorporating POCUS into their clinical practice, and POCUS-IVC and JVP are, collectively, the second most commonly performed examinations by rural generalist physicians in New Zealand (NZ).[13,14] POCUS does, however, add to the time it takes to assess a patient and requires an investment in training and equipment. Its role has not previously been examined in the rural context, and it is not known how often the experienced rural physician gains additional new useful clinical information by taking the time to perform POCUS-IVC and JVP, and how often, they are merely confirming the impression of a patient's volume that they have already obtained by the physical examination.

The aim of this study is to determine as follows: (i) the quality of interpretation of POCUS-IVC and JVP imaging; (ii) the indications for POCUS and (iii) the correlation between the findings of physical examination and the findings of POCUS plus physical examination, for the assessment of intravascular volume, in the rural context.

METHODS

This report presents results for the subgroup of POCUS-IVC and JVP examinations undertaken as a part of a larger study into the POCUS practice of 28 rural generalist physicians (the participants). All the participants were trained in general practice and/or rural hospital medicine by the Royal NZ College of General Practitioners and were working in six small NZ rural hospitals/health services, ranging in size from 10 to 30 inpatient beds and serving communities with resident populations between 6500 and 36,000. The study recorded the frequency of scan types undertaken, the quality of the images obtained and the impact on patient management, over a 9-month period. This was achieved by asking the participants to complete a questionnaire pre- and post-test and by reviewing the POCUS images and patient's clinical records.[13,14] Results and more detailed methods for the larger study, including the characteristics of the participants and their rural hospitals, are reported elsewhere.[13,14]

During the study, the participants were encouraged to continue using POCUS, as they normally would while undertaking their routine clinical duties. This included choosing when to perform a POCUS-IVC or POCUS-JVP. Before undertaking POCUS for volume assessment, the participant recorded on a questionnaire, their estimate of the patient's volume based on their physical examination findings, using an 11-point visual analogue scale. The middle of the scale, six, meant that the patient was euvolaemic. The lowest end of the scale – one, indicated the patient was severely hypovolaemic and at the other end-11, severely volume overloaded. After completing the POCUS, the participants reevaluated the patient's volume and recorded a post-test result using the same scale. The questionnaire also recorded the indication for the POCUS scan and the participant's assessment of the quality of the images they had obtained.

The participants were asked to keep electronic copies of POCUS-IVC images which were reviewed at a later date by a sonographer. POCUS of the JVP involves measuring the height relative to the angle of Louis, something that cannot be checked with saved images.

Statistical analysis was performed using the SPSS version 23 (SPSS Statistics Version 23. IBM Corporation. Armonk. New York. United States). Descriptive statistics were used to describe outcomes. The Spearman's correlation coefficient and a Bland–Altman plot were used to illustrate the correlation between the physical examination and combined (POCUS and physical examination) findings.

Ethics approval was obtained from the NZ Multi-region Ethics Committee MEC/10/09/091.

RESULTS

Twenty participants in five different rural hospitals undertook 154 POCUS assessments of intravascular volume over the study period. There was considerable variation among the five hospitals in the frequency of POCUS-IVC and JVP scanning (between 5 and 85 scans).[13] No POCUS-IVC or JVP scans were performed in the sixth hospital and by eight of the participants. The median age of the patients scanned was 72 years, ranging from 13 to 98 years. The IVC was scanned in 126 patients, the JVP in 10 and 18 patients had both IVC and JVP scanned.

The indication for POCUS was available for 97% (150/154) of the patients. The most common indications were: (i) potential dehydration and (ii) heart failure [Table 1].

On 7 (4.8%) out of 144 occasions, participants reported being unable to obtain images of the IVC that were of diagnostic quality. None of the participants reported difficulty in obtaining images of the JVP. Sixty-six IVC images were available for review by the sonographer. This review identified two errors (2/66), in both cases, the aorta had been mistaken for the IVC.

The physical examination and POCUS estimations of the patient's volume were recorded

Table 1: Indication* for point-of-care ultrasound scan of the inferior vena cava/jugular venous pulse by the rural physicians

	n (%)
Blood loss	7 (5)
Undifferentiated collapse	2 (1)
Heart failure	55 (37)
Dehydration	73 (48)
Renal failure	3 (2)
Sepsis	10 (7)
Total	150 (100)

*Presentation or actual/potential diagnosis.

on the questionnaire for 97% (150/154) of the patients. The mean difference between the estimation of volume by the physical examination and combined POCUS/physical examination was 1.9 steps (standard deviation 1.45) on the visual scale. There was an only moderate agreement between the findings as illustrated in the Bland–Altman plot [Figure 1] and by the Spearman's correlation coefficient (0.46, n = 150, P = 0.000). Figure 2 illustrates the frequency of the differences between the physical examination and combined POCUS/physical examination findings. For 21% (31/150), there was no difference between the findings and for a further 19% (28/150), the difference was only one on the visual scale, and therefore, unlikely to be clinically relevant. In 28% (42/150) of cases, the difference was four or more points, and therefore, likely to be clinically significant. In the remaining 32% (49/150), the difference was two or three, which may or may not have been clinically significant. Thirty percent (9/30) of patients who were clinically volume overloaded were hypovolaemic by POCUS, and 15% (14/93) of patients who were clinically volume depleted had volume overload on the basis of POCUS.

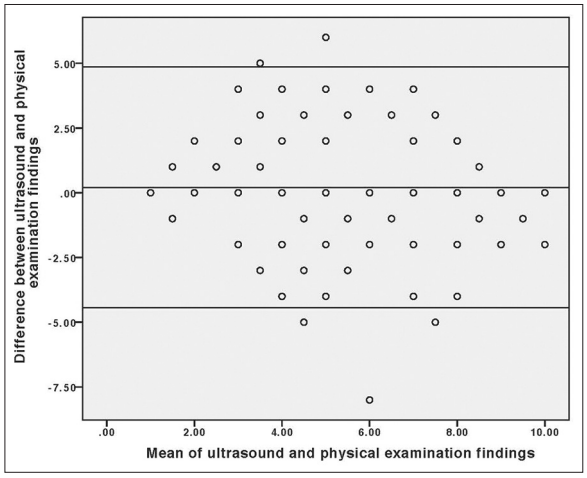


Figure 1: Bland–Altman Plot of correlation between point-of-care ultrasound and physical examination findings for estimation of intravascular volume. (The scatter in the plot demonstrates the frequently large differences in the estimations of intravascular volume, based on POCUS plus physical examination versus physical examination alone, for patients regardless of whether their intravascular volumes are low, normal, or high). X-axis: Mean of estimation of patient's volume by (1) physical examination and (2) ultrasound plus physical examination. Y-axis: Difference between the estimation of patient's volume by (1) physical examination and (2) ultrasound plus physical examination. Both axes are based on a visual scale of estimated intravascular volume status from 1 to 11. 6 = the patient was euvolaemic. 1 = patient was severely hypovolaemic and 11 = severely volume overloaded.

DISCUSSION

In this study, POCUS frequently altered a physician's impression of a patient's intravascular volume compared to the one they had formed on the basis of physical examination alone. It was not uncommon for a patient judged to be hypovolaemic by physical examination to be considered volume overloaded after POCUS and vice versa. Sometimes, the differences were large [Figure 2]. On the basis of these results, POCUS is providing new clinical information in this context.

Bowel gas in the upper abdomen sometimes obscures the IVC (particularly in unfasted patients), as happened on seven occasions in this study. The two instances identified in this study in which participants mistook the aorta for the IVC are more concerning. This is an avoidable error and one that needs to be noted by those who practise and teach POCUS.

The success rates for obtaining POCUS-JVP images of diagnostic quality in this study (100%) are the same as in other published studies.[15] Because it is such a superficial structure, POCUS-JVP is technically straightforward and easy to learn.[4,16] The participants chose to perform POCUS-IVC more often than POCUS-JVP.

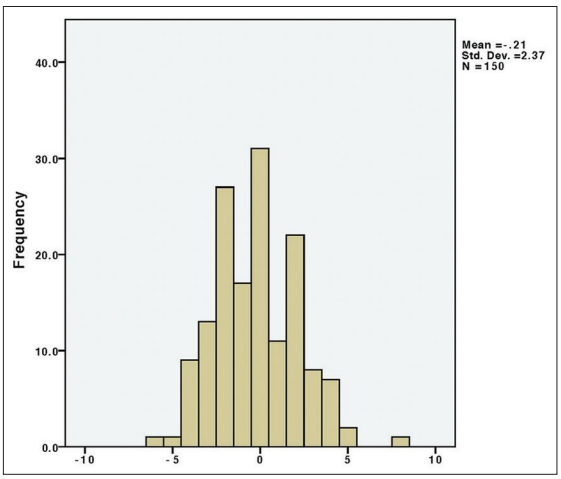


Figure 2: Frequency of differences between point-of-care ultrasound findings and physical findings. X-axis: Difference between the estimation of patient's volume by (1) physical examination (pre-test) and (2) ultrasound plus physical examination (post-test). Based on a visual scale of the estimated intravascular volume status from 1 to 11. Zero means no difference between the findings.

This is likely to be because POCUS of the IVC has a stronger evidence base and as a more central vein, is likely to be a better predictor of the CVP.[6] POCUS of the IVC may also be more convenient, especially if the patient is already lying flat for a physical or other POCUS examination. POCUS-JVP usually requires the patient to be carefully repositioned.

The results of this study support existing evidence that POCUS-IVC and POCUS-JVP are easily learned techniques that are more reliable than physical examination.[2,4,6,8]

Strength and limitations

The real-world nature of this study is a strength. The participants in the study decided when to perform POCUS and which technique to use, based on the clinical indications, just as they would in their routine clinical duties. It is likely the patients in this study comprised a group that was particularly hard to assess clinically, chosen because the physician was still uncertain about their volume status after a physical examination. The variation between physical examination and POCUS findings in this study is, therefore, likely to be larger than would be expected if a random or consecutive series of patients had been scanned. The same real-world nature of the study is responsible for its limitations. The numbers are small and it is unknown if participants recorded data for all of the patients they scanned during the study. Participants also frequently failed to save images of their POCUS scans. The study also did not directly measure whether or not the POCUS findings resulted in a change in clinical management.

The participants in this study were practising the typically broad scope of rural generalist medicine in NZ that traverses primary, secondary and emergency care. This rural generalist scope frequently involves managing acutely unwell undifferentiated patients with limited access to diagnostics, including invasive monitoring.[17] It is not surprising that physicians working in this context will make use of new diagnostic modalities, such as POCUS, that can be practically adopted and resourced in their context.[13]

Further research is needed to determine if POCUS for volume assessment results in improved patient outcomes.

CONCLUSION

POCUS of either the JVP or the IVC are practical alternatives for the estimation of a patient's intravascular volume that can be reliably performed by rural physicians. In many instances, the results obtained differed markedly from those obtained by physical examination alone, and therefore, had the potential to alter the patient management. When a rural doctor with the relevant POCUS skills is unsure of a patient's volume status, it is worthwhile for them to take the time to perform POCUS of the JVP or IVC.

Financial support and sponsorship: The study was financially supported by Partnership grant from the NZ Health Research Council.

Conflicts of interest: There are no conflicts of interest.

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