Data availability and feasibility of various techniques to predict response to volume expansion in critically ill patients

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ABSTRACT

Objective: The accuracy of various techniques to predict response to volume expansion in shock has been studied, but less well known is how feasible these techniques are in the ICU.

Methods: This is a prospective observation single-center study of inpatients from a mixed profile ICU who received volume expansion. At time of volume expansion, we determined whether a particular technique to predict response was feasible, according to rules developed from available literature and nurse assessment.

Results: We studied 214 volume expansions in 97 patients. The most feasible technique was central venous pressure (50%), followed by vena cava collapsibility, (47%) passive leg raise (42%), and stroke volume variation (22%). Aortic velocity variation, and pulse pressure variation, and were rarely feasible (1% each). In 37% of volume expansions, no technique that we assessed was feasible.

Conclusions: Techniques to predict response to volume expansion are infeasible in many patients in shock.

Key Words: Fluid, passive leg raise, shock

INTRODUCTION

Volume expansion is a mainstay of treatment for shock. Inappropriate volume expansion results in pulmonary edema, prolonged time on a ventilator, and increased mortality. One technique to predict the success of volume expansion is measurement of central venous pressure (CVP). This technique, although commonplace, has poor predictive ability.¹ Newer techniques may offer superior predictive ability,²⁻⁶ but may be applied only in selected patient populations or may not function in certain physiologic states.³⁻⁷

While several investigations compare the accuracy of these techniques,⁶⁻⁸ less known is how applicable they are in a general Intensive Care Unit (ICU) population. The passive leg raise (PLR) may be inapplicable in a patient with abdominal hypertension.⁸ Similarly, echocardiography may be impossible in someone with left-sided chest trauma.

We wanted to determine the feasibility of various techniques in the critically ill population receiving volume expansion.

METHODS

This prospective observational cohort study was Institutional Review Board-approved with waiver of informed consent.

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of informed consent. We enrolled patients over a 6-month period from Intermountain Medical Center’s Shock-Trauma ICU, a tertiary care, academic 24-bed ICU that routinely admits medical, surgical, and trauma patients in shock. Clinicians at this ICU use multiple techniques to predict successful volume expansion.

We studied patients who received a clinically indicated volume expansion for shock. At the time of the volume expansion, the nurse recorded patient’s heart rhythm and whether there was sufficient time (4 min) to delay the volume expansion to perform a PLR. We recorded specific clinical states (receipt of ventilation, abdominal hypertension, etc.) that affect the accuracy of various techniques. We evaluated whether the following could have been assessed: PLR by noninvasive cardiac output monitor, vena cava collapsibility (VCC) or aortic velocity variation (AoVV) by ultrasound, stroke volume variation (SVV) by pulse contour analysis, CVP, and pulse pressure variation (PPV). These techniques were not actually performed. We a priori defined indications for each technique for predicting response to volume expansion based on whether it was feasible [Table 1]. We report percentages using simple descriptive statistics.

### RESULTS

We studied 214 volume expansions in 97 patients. Half of the patients had septic shock. Ten percent of patients had irregular heart rhythms at the time of volume expansion, and 38% were receiving mechanical ventilation. No patient had active airways obstruction, and only 3% of patients had acute respiratory distress syndrome. An arterial catheter was present in 47% of patients, and a central venous catheter in 42%. In 33% of volume expansions, the nurse indicated insufficient time (4 min) to perform a PLR before administering the volume expansion. In 30% of volume expansions, patients were receiving a vasopressor or an inotrope.

The most feasible technique was CVP (50% of volume expansions), followed by VCC (47%) and PLR (42%). Feasibility of CVP was essentially an observation that central venous catheters were absent in about 50% of volume expansions. Although nursing perception of insufficient time may be subjective, PLR was infeasible for other reasons, 34% of the time [Table 1]. AoVV, PPV, and SVV were rarely feasible (1.4%, 0.9%, 0.9%, respectively) because passive ventilation is uncommon in the study ICU.

In 37% of volume expansions, no single technique was feasible. In 63% of volume expansions, either PLR or VCC was feasible.

### DISCUSSION

Before this study, it was uncertain how frequently a technique to predict volume expansion would be both available and feasible in a general ICU. For example, CVP, which has poor accuracy in predicting volume expansion,[6] appears to be the most feasible technique, while SVV, which has excellent accuracy in specific physiologic states,[7] is infeasible for most patients.

PLR has some renewed enthusiasm in predicting response to volume expansion because it is applicable in the setting of heart arrhythmia and spontaneously breathing.[6] However, the maneuver requires two measurements of cardiac output, both of which require 2 min of equilibration. The time for the PLR measurement could be halved if the patient had a semi-recumbent baseline position, but this was not standard at the study hospital.

### Table 1: List of techniques to predict response to volume expansion and their indications, based on review of published evidence at time of writing this manuscript

| Technique                  | Unmeasurable in these conditions | Unreliable in these conditions |
|----------------------------|----------------------------------|--------------------------------|
| PLR                        | Nurse unable to delay volume expansion to perform PLR (72) | Pregnancy (0) |
|                            | PLR contraindicated due to intracranial hypertension (4), abdominal surgery (51), or unstable hip fracture (11) | Lower extremity amputation (8) |
| VCC by echocardiography    | Postoperative from abdominal surgery, abdominal dressings or abdominal air (51) | Abdominal hypertension (0) |
| SVV by pulse contour       | No arterial catheter present (91) | Active airways obstruction (0) |
| SVV by echocardiography    | Left-sided chest trauma, thoracostomy, or surgery with dressing overlying the apical echocardiographic window (8) | Spontaneous ventilation (120) |
| PPV                        | No arterial catheter present (91) | Assisted ventilation (91) |
| CVP                        | No central venous catheter present (107) | Active airways obstruction (0) |

Parentheses indicate the number of volume expansions meeting a specific condition, out of 214 volume expansions. Some patients met more than one condition. PLR: Passive leg raise, VCC: Vena cava collapsibility, SVV: Stroke volume variation, PPV: Pulse pressure variation, CVP: Central venous pressure.
This study has several limitations. This study did not necessarily perform all the various techniques for each volume expansion and therefore cannot compare diagnostic accuracy between different techniques. The reliance on nurse participation could cause selection bias. We omitted several techniques: lithium dilution SVV, pulmonary artery catheter pressure, and continuous cardiac output monitor. We excluded these techniques because our ICU does not routinely use them. Although we based our rules for data availability and feasibility on published evidence, there may be expert disagreement. An example is that some may consider PPV applicable in spontaneously breathing mechanically ventilated patients. We excluded this application because it requires a ventilator setting that we do not routinely use and defines successful volume expansion as a change in arterial pressure rather than cardiac output.

CONCLUSION

Techniques to predict successful volume expansion are infeasible in many patients in shock.

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Conflicts of interest
There are no conflicts of interest.

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