Predicting Fluid Responsiveness in ICU Patients*

A Critical Analysis of the Evidence

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Study objective: **To identify and critically review the published peer-reviewed, English-language studies investigating predictive factors of fluid responsiveness in ICU patients.**
Design: **Studies were collected by doing a search in MEDLINE (from 1966) and scanning the reference lists of the articles. Studies were selected according to the following criteria: volume expansion performed in critically ill patients, patients classified in two groups (responders and nonresponders) according to the effects of volume expansion on stroke volume or on cardiac output, and comparison of responder and nonresponder patients' characteristics before volume expansion.**
Results: **Twelve studies were analyzed in which the parameters tested were as follows: (1) static indicators of cardiac preload (right atrial pressure [RAP], pulmonary artery occlusion pressure [PAOP], right ventricular end-diastolic volume [RVEDV], and left ventricular end-diastolic area [LVEDA]); and (2) dynamic parameters (inspiratory decrease in RAP [ΔRAP], expiratory decrease in arterial systolic pressure [Δdown], respiratory changes in pulse pressure [ΔPP], and respiratory changes in aortic blood velocity [ΔVpeak]). Before fluid infusion, RAP, PAOP, RVEDV, and LVEDA were not significantly lower in responders than in nonresponders in three of five studies, in seven of nine studies, in four of six studies, and in one of three studies, respectively. When a significant difference was found, no threshold value could discriminate responders and nonresponders. Before fluid infusion, ΔRAP, Δdown, ΔPP, and ΔVpeak were significantly higher in responders, and a threshold value predicted fluid responsiveness with high positive (77 to 95%) and negative (81 to 100%) predictive values.**
Conclusion: **Dynamic parameters should be used preferentially to static parameters to predict fluid responsiveness in ICU patients.** ***(CHEST 2002; 121:2000–2008)***

Key words: arterial pressure; cardiac output; cardiac preload; fluid responsiveness; left ventricular end-diastolic area; pulmonary artery occlusion pressure; right atrial pressure; right ventricular end-diastolic volume; stroke volume; volume expansion

Abbreviations: Δdown = expiratory decrease in arterial systolic pressure; LVEDA = left ventricular end-diastolic area; PAOP = pulmonary artery occlusion pressure; PEEP = positive end-expiratory pressure; ΔPP = respiratory changes in arterial pulse pressure; RAP = right atrial pressure; ΔRAP = inspiratory decrease in right atrial pressure; RVEDV = right ventricular end-diastolic volume; ΔVpeak = respiratory changes in aortic peak velocity

Volume expansion is frequently used in critically ill patients to improve hemodynamics. Because of the positive relationship between ventricular end-diastolic volume and stroke volume,[1] the expected hemodynamic response to volume expansion is an increase in right ventricular end-diastolic volume (RVEDV), left ventricular end-diastolic volume, stroke volume, and cardiac output. The increase in end-diastolic volume as a result of fluid therapy depends on the partitioning of the fluid into the different cardiovascular compliances organized in

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series. The increase in stroke volume as a result of end-diastolic volume increase depends on ventricular function since a decrease in ventricular contractility decreases the slope of the relationship between end-diastolic volume and stroke volume.[1] Therefore, only 40 to 72% of critically ill patients have been shown to respond to volume expansion by a significant increase in stroke volume or cardiac output in studies[2–13] designed to examine fluid responsiveness. This finding emphasizes the need for predictive factors of fluid responsiveness in order to select patients who might benefit from volume expansion and to avoid ineffective or even deleterious volume expansion (worsening in gas exchange, hemodilution) in nonresponder patients, in whom inotropic and/or vasopressor support should preferentially be used.

Bedside indicators of ventricular preload have been proposed as predictors of fluid responsiveness.[2–4,6–9,11–13] In this regard, a postal survey in Germany showed that right atrial pressure (RAP) and pulmonary artery occlusion pressure (PAOP) are used by a majority of ICU physicians when deciding to administer fluid,[14] and several recommendations support the use of cardiac filling pressures in order to guide fluid therapy in critically ill patients.[15,16] Other bedside indicators of ventricular preload, namely RVEDV and left ventricular end-diastolic area (LVEDA), have also been tested as predictors of the hemodynamic effects of volume expansion in critically ill patients.[2–4,6–9,11,13]

The respiratory changes in RAP, arterial pressure, and aortic blood velocity, assumed to be dynamic indicators of the sensitivity of the heart to changes in preload induced by changes in pleural pressure, have also been proposed to predict fluid responsiveness in critically ill patients.[5,9,10,12,13] Therefore, the aim of the present study was to analyze the clinical studies investigating predictive factors of fluid responsiveness in critically ill patients in order to assess the value of each parameter tested.

Materials and Methods

Selection of Studies To Be Evaluated

We collected studies investigating the predictive factors of fluid responsiveness in critically ill patients by doing a search in MEDLINE (from 1966). Studies were selected according to the following criteria: volume expansion performed in critically ill patients, patients classified in two groups (responders and nonresponders) according to the effects of volume expansion on stroke volume or on cardiac output, and comparison of responder and nonresponder patients characteristics before volume expansion. The reference lists of the selected articles were scanned for additional studies. Of the 12 included studies,[2–13] 11 studies were identified from the electronic database and 1 study was identified from reference tracing.[5] The main characteristics of these studies are presented in Table 1.

Parameters Tested as Predictors of Fluid Responsiveness

Ten studies have investigated the value of ventricular preload indicators in predicting fluid responsiveness. The parameters tested were RAP in five studies,[2–4,8,12] PAOP in nine studies,[2–4,6–9,11,12] RVEDV in six studies,[2–4,6–8] and

Table 1—*Main Characteristics of Clinical Studies Investigating the Predictive Factors of Fluid Responsiveness in ICU Patients**

Source	Patients, No.	FC, No.	Fluid Infused	Volume Infused, mL	Speed of FC, min	Definition of Response	Rate of Response, %	Parameters Tested
Calvin et al[2]	28	28	5% Alb	250	20–30	ΔSV > 0%	71	RAP, PAOP, RVEDV
Schneider et al[3]	18	18	FFP	500	30	ΔSV > 0%	72	RAP, PAOP, RVEDV
Reuse et al[4]	41	41	4.5% Alb	300	30	ΔCO > 0%	63	RAP, PAOP, RVEDV
Magder et al[5]	33	33	9% NaCl	100–950		ΔCO > 250 mL/min	52	ΔRAP
Diebel et al[6]	15	22	R. lactate Colloids	300–500 500		ΔCO > 10%	59	PAOP, RVEDV
Diebel et al[7]	32	65	R. lactate	300–500		ΔCO > 20%	40	PAOP, RVEDV
Wagner and Leatherman[8]	25	36	9% NaCl 5% Alb, FFP	938 ± 480 574 ± 187	7–120	ΔSV > 10%	56	RAP, PAOP, RVEDV
Tavernier et al[9]	15	35	HES	500	30	ΔSV > 15%	60	PAOP, LVEDA, Δdown
Magder and Lagonidis[10]	29	29	25% Alb 9% NaCl	100 150–400	15	ΔCO > 250 mL/min	45	ΔRAP
Tousignant et al[11]	40	40	HES	500	15	ΔSV > 20%	40	PAOP, LVEDA
Michard et al[12]	40	40	HES	500	30	ΔCO > 15%	40	RAP, PAOP, ΔPP
Feissel et al[13]	19	19	HES	8 mL/kg	30	ΔCO > 15%	53	LVEDA, ΔVpeak
Total	334	406					52	

*FC = fluid challenge; Alb = serum albumin; FFP = fresh frozen plasma; NaCl = serum saline solution; R. lactate = Ringer's lactate; HES = hydroxyethylstarch; ΔSV = volume expansion-induced changes in stroke volume; ΔCO = volume expansion-induced changes in cardiac output.