Fluid loading responsiveness

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Chapter 4

Hemodynamic assessment in Dutch intensive care units

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The prolonged presence of hypovolaemia seriously impairs oxygen delivery to vital organs, hence fluid loading is indicated [1]. However, unnecessary fluid administration can lead to general and pulmonary oedema and cardiac failure [1,2]. Therefore, the selection of patients that will benefit from fluid administration is critical.

This selection is traditionally based on clinical signs such as urine colour and production, as well as on filling pressures such as central venous pressure (CVP) and pulmonary artery wedge pressure (PAWP). In 1998, Boldt and colleagues performed a survey and reported that 93% of all ICU physicians in Germany used CVP and 58% used PAWP to assess volume status [3]. Nevertheless, neither clinical signs nor filling pressures have unambiguously been shown to discriminate between those patients who benefit from fluid loading and those who do not [4-6]. In most studies, this beneficial effect was defined as a significant increase in cardiac output. Because, in principle, nearly all patients will experience an increase in cardiac output after fluid loading [7], there is a necessity to differentiate between an increase in measured cardiac output (CO) after fluid loading and a "clinically" significant increase in CO. In fluid-loading-responsiveness studies, responders and non-responders are divided by an increase of 10% in CO after approximately 500 ml of fluid loading. Furthermore, the presence of fluid-responsiveness does not imply the need for fluid loading. Not only the

ability to accurately predict the effect on CO after fluid loading is important but, for instance, also tissue O_2 in the different organs and outcome need more attention.

In recent years, new variables based on heart-lung interaction, i.e. respiratory-induced stroke volume variation (SVV), pulse pressure variation (PPV) and systolic pressure variation (SPV), have been introduced [8]. These variables have been studied extensively but results regarding their predictive value in identifying responders and non-responders on fluid loading have been contradictory [9-11]. In addition, loading the circulation with small amounts of fluid (up to 500 ml) [12], or by passive leg raising (PLR) [7, 13-17] have become the subject of intense interest in assessing fluid loading responsiveness (or in other words to identify patients who will benefit from fluid loading).

We evaluated the impact of newly derived variables (SVV, PPV and SPV), fluid challenges and PLR, and new cardiac output devices in daily practice in Dutch intensive care units. Finally, we investigated the use of guidelines to monitor volume status and fluid responsiveness in the ICU.

Materials and methods

A questionnaire was sent via the Dutch Society of Intensive Care (NVIC) to 446 Dutch intensive care physicians (i.e. intensivists and fellows) working in one of the 99 hospitals with an ICU in the Netherlands. In the Netherlands, most intensive care physicians are members of the NVIC. A cover letter was included to provide background information and a stamped addressed return envelope was added. The questionnaires were sent by regular mail in March 2008.

The questionnaire was designed to be answered within 10 minutes. The questionnaire was checked by a sociologist with experience in the design of surveys. The majority of questions were multiple choice. The questionnaire consisted of seventeen questions and covered three topics: 1. General characteristics of ICU physicians; prior specialty training, experience level, type of hospital; 2. Assessment of haemodynamic condition and treatment of patients; use of clinical signs, haemodynamic parameters and challenges to the circulation; 3. Guidelines used in the ICU; definitions of hypovolaemia and hypervolaemia, use of guidelines, date of guideline update. The questionnaire was in Dutch. A translation is shown in the appendix. Questionnaires were collected up to one month after being sent. The completed questionnaires were returned anonymously.

Because of the exploratory character of the data, analysis consisted of descriptive techniques and chi-square tests when appropriate (SPSS 14.0.1 for Windows, SPSS Inc., Chicago, IL). Results are expressed in frequencies. A p-value of ≤ 0.05 was regarded significant.

Results

General characteristic of ICU physicians

Altogether 176 of 446 (39%) questionnaires were returned. Respondents were predominantly specialized in internal medicine and anaesthesiology, the experience level within these two specialties was not significantly different (χ^2, p=0.079). Characteristics of respondents are shown in Table 1.

Table 1 Respondent characteristics (in % of all respondents).

Specialization	Anaesthesiology	45
	Internal Medicine	44
	Surgery	4
	Paediatrics	3
	Neurology	1
	Pulmonology	2
	Cardiology	1
Experience level	Fellow	7
	0-5 years	40
	5-10 years	14
	> 10 years	38
Type of hospital	Non-university	76
	University	24

Assessment of haemodynamic condition and treatment of patients

The clinical signs most often used by Dutch ICU physicians in their initial assessment are shown in Table 2. Urine colour and production as well as capillary refill were the most used. Combinations of clinical signs used were urine production and blood pressure (19%), capillary refill and blood pressure (10%), capillary refill and heart rate (8%). We requested respondents to circle up to two clinical signs, however, 10% of respondents marked more than five clinical signs. These respondents indicated to use a wide variety of clinical signs in their assessment.

To estimate the need for volume expansion, the haemodynamic status was further investigated using the parameters mentioned in Table 3. Clearly, CVP is the most used parameter (70%). Surprisingly, SVV, SPV or PPV were used by 47% of all respondents. MAP and CO were considered by 33% and 19% of the physicians to be the most important predictive parameters. At 31%, the combination of CVP and SVV or PPV or SPV was the most used (Table 4). Remarkably, CVP was mentioned in most combinations.

Table 2 Clinical signs used in the assessment of volume status.

Clinical signs	**Frequency (in %)**
Urine colour or production	39
Capillary refill	28
Blood pressure	7
More than five clinical signs	10
Skin turgor	7
Body temperature	5
Dry mouth	1
Fluid balance	2
Heart rate	1

Table 3 Parameters used in the assessment of volume status.

Parameter	**Frequency (in %)***
CVP	70
SVV, PPV or SPV	47
MAP	33
Serum urea and creatinine	22
CO	20
SvO_2	20
Urine sodium	15
TEE	14
PAWP	12
Serum lactate	8
SAP	4
LVED	2
Shape of arterial wave	1

* Total frequency exceeds 100% since multiple parameters can be used by a respondent

Table 4 Most used combinations of parameters in the assessment of volume status.

Parameters	Frequency (in %)
CVP & SVV, PPV, SPV	31
CVP & MAP	22
CVP & Urea/ creatinine	17
SVV, PPV, SPV & CO	11
CVP & Urine sodium	11
CVP & CO	10
CVP & SvO_2	10
MAP & SVV, PPV, SPV	10
CVP & TEE	7
CVP & Lactate	6
MAP & Urine sodium	6
SVV, PPV, SPV & SvO_2	6
SVV, PPV, SPV & TEE	7
SVV, PPV, SPV & Urea/ creatinine	6

If cardiac output was monitored: the pulmonary artery catheter was used by 65%, PiCCO (Pulsion Medical Inc., NJ, USA) by 15%, trans-oesophageal echocardiography by 11%, Vigileo/ FloTrac (Edwards Lifesciences, CA, USA) by 5%, NICO (Novametrix Medical Systems Inc, CT, USA) by 4%, and trans-thoracic echocardiography by 2%. Forty-four percent of these respondents could choose from two or more devices to monitor cardiac output.
To predict which patients would benefit from fluid loading, the effect of passive leg raising (PLR) was used as an integral part of volume status monitoring by 2% of the respondents. Twenty-seven percent never used PLR, 21% seldom used PLR, 35% occasionally used PLR and 17% often used PLR. Interestingly, 10% of respondents always used a fluid loading challenge, 66% used it often, 21% sometimes and 3% seldom or never.
When a PLR or fluid challenge was applied, the majority of respondents monitored changes in heart rate, MAP and CVP to predict fluid loading responsiveness. Forty-two percent used one parameter, 34% used two parameters, and 24% used three or more parameters to make their assessment. In Table 5, an overview is given of the parameters used in the passive leg raising and fluid challenge.

Table 5 Eight most often used parameters during a fluid loading challenge or passive leg raising to predict fluid loading responsiveness.

Parameters	Frequency (in %)*
Heart rate	59
MAP	48
CVP	32
CO	21
Urine production	17
SVV, PPV or SPV	10
SAP	6
SvO_2	3

* Total frequency exceeds 100% since multiple parameters can be used by a respondent

Prior specialty training, experience level or type of hospital did not influence the selection of clinical signs or use of haemodynamic parameters to assess volume status. Exceptions were blood pressure and serum lactate which were used more often by physicians with less than five years of experience during initial assessment (10/ 84 vs. 3/ 92 with $p < 0.001$ and 10/ 84 vs. 12/ 92, $p=0.029$, respectively). Skin turgor was used less in the less-than-five-years experience group than in the group of physicians with more than five years experience (2/ 84 vs. 12/ 92 with $p<0.009$).

Guidelines used in ICU

A quarter (n=44) of all physicians have departmental guidelines to assess the hypo- or hypervolaemic status of a patient. Where guidelines were in place, 57% of respondents indicated that they almost always followed these guidelines, whereas 43% seldom followed them. The parameters used in the available guidelines are described in Table 6. Twenty-one percent used a single parameter from their guidelines 24% used two, 41% used three and 14% used four parameters.

Table 6 Frequency of use of haemodynamic parameters in active haemodynamic monitoring guidelines in Dutch intensive care departments.

Parameters	Frequency (in %)*
CVP	55
MAP	43
CO	33
SVV, PPV or SPV	21
Diuresis	36
Heart rate	21
Lactate	10
SvO_2	10
PAWP	7

* Total frequency exceeds 100% since multiple parameters can be used by a respondent

Eighty percent of these guidelines had been updated within the past year. Thirty-four percent of the respondents were unaware which authority was responsible for updating the guideline. A total of 48% of the guidelines were updated by a committee within the Intensive Care department, and 18% were updated by the head of the department. Surprisingly, none of the guidelines had been directly adapted from those of intensive care or anaesthesiology societies. The type of hospital did not influence whether a guideline for haemodynamic assessment was in place or not (p=0.092).

Discussion

In 2006, the Dutch Ministry of Health registered 238,022 adult-patient ventilation-days in ICUs in the Netherlands [18]. We may assume that these patients were continuously monitored and volume status was assessed regularly to optimize tissue perfusion. The aim of this survey was to evaluate the impact of recently introduced parameters and challenges in the daily practice of Dutch intensive care physicians. We mapped the current use of haemodynamic parameters in the assessment of volume status of intensive care patients. In addition, we researched the use of guidelines for haemodynamic monitoring.
Recent publications might have had a relatively high impact on the use of haemodynamic parameters in the assessment of volume status. Although the use of CVP measurement is still high (70%), 47% of physicians use SVV, PPV or SPV and 76% regularly use fluid

challenges in their assessment. There is no uniformity or consensus on the use of parameters in evaluating volume status. This is supported by the low number of ICUs with guidelines for haemodynamic monitoring of volume status and fluid loading. In addition, 43% of physicians reported that they barely used the available guidelines.

The incidence of use of SVV, PPV or SPV is remarkable for several reasons. First, we found that pulse contour devices are used less than thermodilution devices to measure CO. This contrasts the finding that SVV, PPV and SPV are used by 47% and CO by 19%. Second, the use of these parameters in haemodynamic monitoring has primarily been studied in cardiac surgery patients [10, 19, 20]. Third, the use of these parameters is restricted to sedated patients fully dependent on mechanical ventilation [21]. Moreover, the average duration of mechanical ventilation is decreasing due to fast track protocols [22]. Fourth, arrhythmia, a common phenomenon in ICU patients, hampers the use of SVV, PPV and SPV. Fifth, variations in stroke volume and arterial pressure are found to be reliable only when ventilation with larger tidal volumes ($> 8\ ml \cdot kg^{-1}$) are used [8] while ventilation with lower tidal volumes ($< 6\ ml \cdot kg^{-1}$) are advocated in the ARDSnet study for ARDS/ALI patients.
CVP is still frequently used although its use is controversial. In a recent review the authors calculated a pooled area under the receiver operating curve to predict fluid loading responsiveness for CVP of 0.56. They proposed the discontinuation of the routine measurement of CVP to monitor volume status of the patients in the ICU or operating room [23]. Moreover, several studies have shown SVV to be a better predictor of fluid loading responsiveness than CVP [10, 24, 25].
Passive leg raising has been studied for a number of years, and in this survey its use was limited to 17% of the responding intensivists. Although one advantage of PLR over fluid challenge could be the reversibility of the fluid challenge, 76% of respondents indicate using a fluid challenge. These findings become less surprising when we consider that the fluid challenge as well as SVV, PPV or SPV have been the subject of investigation since the 1990's. We hypothesize that considerable time has to elapse before experimental findings become a routine part of clinical care. Nevertheless, it can also be argued that the difference in use of PLR and fluid challenge is explained by the robustness of the fluid challenge.
When a challenge to the circulation is used to assess volume status, heart rate, MAP and CVP are most often used parameters to monitor and predict fluid loading responsiveness. Several of the most-often-used parameters, however, do not concur with recent literature. Change in CVP due to PLR for instance, has been shown to be an unreliable predictor [15]. The reliability of other parameters such as urine production and SvO_2 has not been studied during a challenge. This could also imply that some of the respondents performed another type of fluid challenge.

It must also be noted that the use of lactate is mentioned by only 8% of respondents even though "surviving sepsis" and "early goal directed therapy" clearly advocate the use of lactate [26,27]. This could be explained by the limitation of the number of answers that could be given in this survey. However, SvO_2 is used by 19% of respondents and this parameter is also advocated in both guidelines [26,27].

Other surveys

In Germany in 1997, Boldt and colleagues performed a survey to assess fluid loading strategies in ICUs [3]. In this survey CVP was used by 93% of respondents and PAWP by 58%, while the dynamic parameters SVV, PPV or SPV were barely used [3]. We assume that similar strategies have been used in haemodynamic management in Dutch and German ICUs. In the current survey, the incidence of use of CVP and especially PAWP, is lower and a large group of ICU physicians used SVV, SPV or PPV as parameter.

More recently, in 2006, Kastrup and colleagues sent a questionnaire to the leading physicians of 80 cardiac surgery ICUs in Germany [28]. In this subgroup, CVP, MAP and PAWP were used more frequently (89%, 84% and 33% respectively), while SVV, SPV or SPV was used by only 15% [28]. We attribute differences in Kastrup's and our findings to differences in the surveyed subgroup, time, and/or the country in which the survey was performed, and concomitant differences in the setup of post-registration education programmes.

Considerations

Firstly, although an acceptable return rate of 39% was achieved, inherent to this type of survey, it must be noted that it may not represent all physicians. In contrast, Boldt [3] and Kastrup [28] achieved return rates of around 60%. Secondly, the completed questionnaires were returned anonymously. Hence, we could not determine a no-response bias. Thirdly, some answers could have been 'desired' answers. The finding that 47% of respondents use SVV, PPV and/or SPV to evaluate volume status seems to be at odds with the actual use of pulse contour methods (20% of respondents). Lastly, the group of physicians with an academic position seems overrepresented as we got 24% respondents from academic hospitals whereas actually only 8% of ICU physicians have an academic position [18]. However, we could not detect a difference in response, for any of the questions (including usage of guidelines), between the two groups. Therefore, we do not regard this overrepresentation as a significant bias.

Conclusions

The present survey shows that CVP is still the most often used parameter to guide fluid loading. However, Dutch ICU physicians are remarkably compliant in using recently developed and published dynamic parameters as SVV and PPV as well as fluid challenges.

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Appendix Questionnaire volume status assessment and fluid loading

1. What is your specialty training, besides intensive care medicine? **Circle your choice:**
   a. Anaesthesiology
   b. Cardiology
   c. Cardiac surgery
   d. Surgery
   e. Internal medicine
   f. Pulmonology
   g. Neurosurgery
   h. Neurology
   i. Other, ______________________________________

2. How long have you been an intensive care physician? **Circle your choice:**
   a. Fellow
   b. 0-5 years
   c. 5-10 years
   d. > 10 years

3. In what type of hospital do you work? **Circle your choice:**
   a. University hospital
   b. Non-university hospital

4. Which clinical indicators do you use to decide on further analyses of a patient's volume status? **Please circle a maximum of two choices:**
   a. Skin turgor
   b. Dry mouth
   c. Dry axillae
   d. Urine colour and/or production
   e. Body temperature
   f. Capillary refill
   g. Colour of the extremities
   h. Fluid balance
   i. Blood pressure
   j. Heart rate
   k. Other, ______________________________________

5. Which indicator(s) do you use to determine the volume status of the patient?
Please circle up to three of your choices:
   a. Central venous pressure
   b. Mean arterial pressure
   c. Pulmonary arterial pressure
   d. Systolic arterial pressure
   e. Pulmonary arterial wedge pressure
   f. Dynamic parameters: SVV, PPV or SPV
   g. Cardiac output
   h. PaO_2
   i. SvO_2
   j. Trans-oesophageal Doppler echography
   k. Plasma urea, creatinine or electrolytes
   l. Urine sodium
   m. Serum lactate
   n. Other, ___________________________________

6. When you determine cardiac output, which device do you use? **Circle your choice(s):**
   a. None
   b. Pulmonary artery catheter (thermodilution bolus/ continue)
   c. Trans-pulmonary thermodilution
   d. Trans-oesophageal Doppler
   e. Pulse contour - PiCCO
   f. - LidCO
   g. - Vigileo/ Flotrac
   h. Other, ___________________________________

7. Do you use passive leg raising (PLR) to determine the volume status of your patients? **Circle your choice:**
   a. Never
   b. Seldom
   c. Once in a while
   d. Often
   e. Always

8. Do you use fluid challenges to assess the volume status of your patients? **Circle your choice:**
   a. Never
   b. Seldom
   c. Once in a while
   d. Often
   e. Always

9. If you use PLR and/or fluid challenges, which parameters do you use to determine the outcome?

   Parameter(s): ____

10. Are there guidelines or protocols in your ICU in which parameters for hypo- or hypervolaemia are used. If yes, which parameters? **Please circle your choice:**
   a. No
   b. Yes, the parameter(s) are: ____

11. If such guidelines exist, do you use the definition for hypo- or hypervolaemia? **Please circle your choice:**

Hypovolaemia:		Hypervolaemia:	
a.	Always	a.	Always
b.	Often	b.	Often
c.	Once in a while	c.	Once in a while
d.	Seldom	d.	Seldom
e.	Never	e.	Never
f.	Not defined	f.	Not defined

12. Are there guidelines in use in your ICU on how to perform fluid loading? **Please circle your choice:**
   a. Yes, please continue with the next question
   b. No, this is the end of the questionnaire

13. Do you use these guidelines for fluid loading in your treatment? **Please circle your choice:**
   a. Always
   b. Often
   c. Once in a while
   d. Seldom
   e. Never

14. If yes (question 12), when were these guidelines last updated? ____/____/____

15. Who is responsible for keeping these guidelines up to date? **Please circle your choice:**
   a. A committee related to the ICU
   b. A committee related to another department in the hospital
   c. A society or organization, namely; _________________
   d. Head of the department

88)