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Original Article

Haemodynamic monitoring and management in COVID-19 intensive care patients: an International survey

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ABSTRACT

Purpose: To survey haemodynamic monitoring and management practices in intensive care patients with the coronavirus disease 2019 (COVID-19).
Methods: A questionnaire was shared on social networks or via email by the authors and by Anaesthesia and/or Critical Care societies from France, Switzerland, Belgium, Brazil, and Portugal. Intensivists and anaesthetists involved in COVID-19 ICU care were invited to answer 14 questions about haemodynamic monitoring and management.
Results: Globally, 1000 questionnaires were available for analysis. Responses came mainly from Europe (n = 460) and America (n = 434). According to a majority of respondents, COVID-19 ICU patients frequently or very frequently received continuous vasopressor support (56%) and had an echocardiography performed (54%). Echocardiography revealed a normal cardiac function, a hyperdynamic state (43%), hypovolaemia (22%), a left ventricular dysfunction (21%) and a right ventricular dilation (20%). Fluid responsiveness was frequently assessed (84%), mainly using echo (62%), and cardiac output was measured in 69%, mostly with echo as well (53%). Venous oxygen saturation was frequently measured (79%), mostly from a CVC blood sample (94%). Tissue perfusion was assessed biologically (93%) and clinically (63%). Pulmonary oedema was detected and quantified mainly using echo (67%) and chest X-ray (61%).
Conclusion: Our survey confirms that vasopressor support is not uncommon in COVID-19 ICU patients and suggests that different haemodynamic phenotypes may be observed. Ultrasounds were used by many respondents, to assess cardiac function but also to predict fluid responsiveness and quantify pulmonary oedema. Although we observed regional differences, current international guidelines were followed by most respondents.

Introduction

Little is known about the haemodynamic consequences of the coronavirus disease 2019 (COVID-19) and the haemodynamic management of patients requiring intensive care unit (ICU) admission. These patients have several reasons to become haemodynamically unstable. First, they may be hypovolaemic because of fever and fluid restriction, which has been recommended from hospital admission to limit the development of pulmonary oedema [1,2]. Like any patients with systemic inflammation, they may also have some degree of vasodilation, which may be amplified by sedative drugs during mechanical

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ventilation. Circulating cytokines may induce ventricular dysfunction [3], and, although post-mortem studies suggest it is uncommon, coronavirus-induced myocarditis may be a cause as well of systolic and diastolic dysfunction [4–6]. Mechanical ventilation with positive end-expiratory pressure (PEEP) may impede right ventricular ejection and induce ventricular dilation, which may in turn decrease left ventricular filling (acute *cor pulmonale*) [7,8]. Finally, coagulation disorders are common in COVID-19 patients and pulmonary embolism seems to be more frequent than on the general ICU population [9,10].

Despite these pathophysiological considerations, large observational studies published so far focused on lung injury [11], mentioned myocardial injury and arrhythmia as possible complications [12], but did not report much information about the haemodynamic status and management of critically ill COVID-19 patients. According to a few studies, the proportion of ICU patients requiring vasopressor support ranges between 35 and 95% [13–15].

The World Health Organization (https://www.who.int/publications-detail/clinical-management-of-severe-acute-respiratory-infection-when-novel-coronavirus-(ncov)-infection-is-suspected) and the National Institutes of Health (https://covid19treatmentguidelines.nih.gov/critical-care/hemodynamics/) released recommendations for the haemodynamic management of COVID-19 patients. The Surviving Sepsis Campaign guidelines were quickly updated [1]. The Asian Critical Care Clinical Trials group also published guidelines based on their early experience with the COVID-19 [2]. They all emphasised the importance of ultrasounds to assess cardiac function and the need to predict fluid responsiveness to rationalise fluid management.

An electronic survey was designed to investigate current haemodynamic monitoring and management practices in COVID-19 ICU patients, as well as alignment with recent guidelines.

Methods

A short questionnaire was developed, and the survey was posted online (Google Forms survey). Intensivists and anaesthetists involved in COVID-19 patients care were invited to answer 14 questions about haemodynamic monitoring and management in the ICU (see Appendix A).

From April 25, the survey was shared on social networks or via email (e-blast) by the authors and the French Society of Anaesthesia and Critical Care (SFAR, sfar.org), the Swiss Society of Intensive Care (SGI-SSMI, sgi-ssmi.ch), the International Fluid Academy (IFA, fluidacademy.org), the Brazilian Society of Intensive Care (AMIB, amib.org.br), the Portuguese Society of Anesthesia (SPA, spanestesiologia.pt) and the Portuguese Society of Intensive Care (SPCI, spci.pt).

Questionnaires not filled by an intensivist or an anaesthetist (certified or trainee), or that did not contain geographical information, or with more than 3 unanswered questions were considered invalid. Responses were monitored on a daily basis and the database was locked for analysis after receiving 1000 valid questionnaires. Data are presented as numbers and percentages. Multiple answers were allowed for several questions (see Appendix A) so that cumulative percentages presented in the text or the figures may exceed 100%. Comparisons between regions were done with a Chi-square test. A p value < 0.05 was considered statistically significant.

Results

The survey database was closed on May 16 after receiving 1064 responses. Thirty-four questionnaires were filled by non-intensivists or non-anaesthetists, 28 questionnaires contained more than 3 unanswered questions and 2 questionnaires did not contain geographical information. The remaining 1000 valid questionnaires were used for analysis. Responses came mainly from Europe (n = 460) and America (n = 434) (Fig. 1). Most respondents were intensivists (n = 649), 157 were intensivists and anaesthetists, 114 were anaesthetists, and 80 were trainees. Two hundred thirty-seven respondents had more than 10 years of experience working in the ICU.

A central venous catheter (CVC) was used by almost all respondents (978/998 = 98%) for drug administration but also to measure venous oxygen saturation (744/978 = 76%), central venous pressure (411/978 = 42%) and for the determination of the veno-arterial PCO_2 gradient (344/978 = 35%). Blood pressure was monitored with a radial arterial catheter (869/998 = 87%), an oscillometric brachial cuff (173/998 = 17%) and a femoral catheter (157/998 = 16%).

Proportions of COVID-19 patients who were reported to receive vasopressors and inotropes, and who were reported to have an echocardiographic evaluation are shown in Fig. 2. Reported echocardiographic findings are presented in Fig. 3. In most cases, the ultrasound evaluation was done with a transthoracic probe (858/889 = 97%) and a conventional trolley machine. Hand-held or pocket echo devices were used by 16% of respondents who were using ultrasounds.

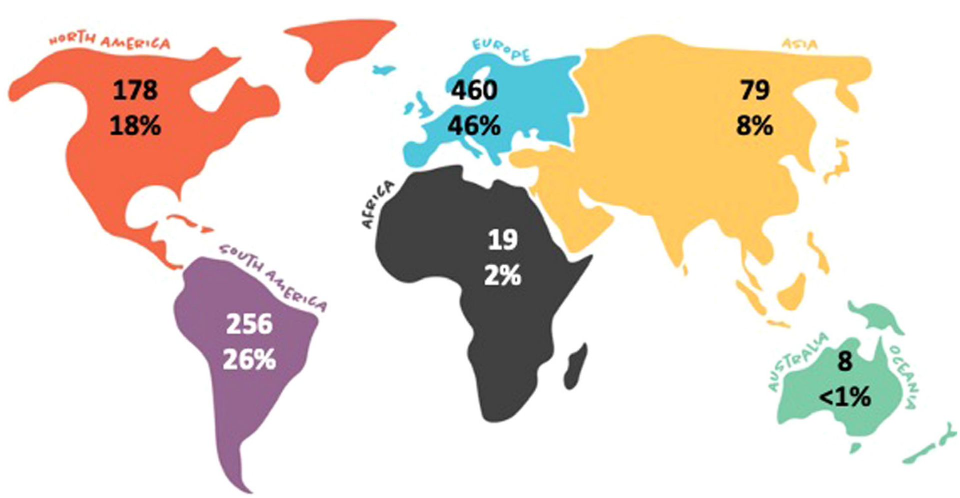


Fig. 1. Geographical location of the 1000 respondents.

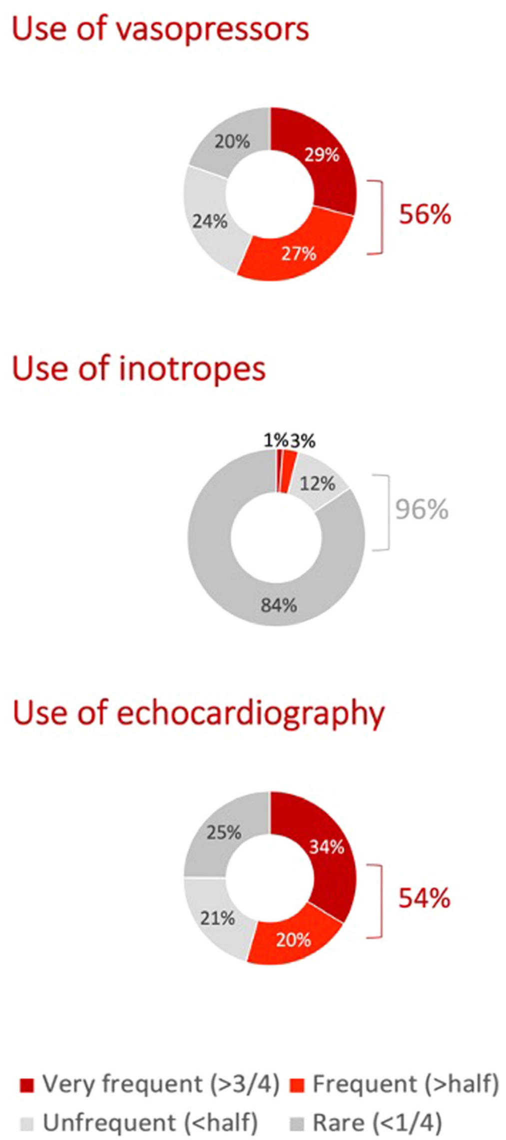


Fig. 2. Use of vasopressors, inotropes and echocardiography.

Fluid responsiveness was assessed by 835/998 (84%) respondents. Methods used to predict fluid responsiveness are presented in Fig. 3. Cardiac output was measured or monitored by 685/997 (69%) respondents. Methods used to measure or monitor cardiac output are presented in Fig. 4.

Venous oxygen saturation was measured by 790/997 (79%) respondents, almost exclusively from a CVC blood sample (Fig. 4). Tissue perfusion was assessed biologically (926/997 = 93%) and clinically (624/997 = 63%). Near InfraRed Spectroscopy (NIRS) and video-microscopy were reported to be used by 31/997 (3%) and 9/997 (1%) respondents, respectively. Pulmonary oedema was reported to be detected and quantified using echo (671/998 = 67%), chest X-ray (605/998 = 61%), auscultation (267/998 = 27%) and transpulmonary thermodilution (208/998 = 21%).

A comparison between the three main geographical areas (Europe, South America and North America) is presented in Fig. 5. To monitor blood pressure, the first choice was the radial catheter in the three main regions. The femoral catheter was less often used in North America (8%) than in Europe (17%, $p < 0.01$) or in South America (21%, $p < 0.01$). To measure cardiac output, ultrasounds were the first choice in the three main regions. Transpulmonary thermodilution was less often used in North America (18%) than in Europe (51%, $p < 0.01$) or in South America (41%, $p < 0.01$). To predict fluid responsiveness, ultrasounds were also the first choice in the three main regions, followed by the pulse pressure variation (PPV) and the passive leg-raising (PLR) manoeuvre in comparable proportions. To assess pulmonary oedema, ultrasounds were the first choice in Europe and in South America, and the second choice after chest X-ray in North America. Extravascular lung water measurements were more often used in Europe (29%) and in South America (21%) than in North America (8%, $p < 0.01$).

Discussion

Our survey confirms that haemodynamic instability is not uncommon in COVID-19 ICU patients and that different haemodynamicprofiles or phenotypes may be observed with echocardiography. From a monitoring standpoint, SvO_2 was reported to be frequently measured from a CVC, and ultrasounds were reported to be widely used, not only to assess cardiac function but also to predict fluid responsiveness and to assess pulmonary oedema. Therefore, current guidelines regarding the use of echocardiography and the need to predict fluid responsiveness were followed by most respondents.

Echocardiographic patterns reported by survey respondents were consistent with cardiovascular clusters recently described in septic shock [16] and underscore the value of ultrasound evaluations to identify the underlying mechanisms of shock and select the most appropriate therapy. Only a minority of echocardiographic evaluations were done using a transesophageal approach. Obesity (frequently reported in COVID-19 patients), mechanical ventilation and prone positioning may render the transthoracic approach challenging. However, the proximity of airways, the risk of aerosol generation and contamination, uncertainties regarding the optimal modalities for probe cleaning, as well as time constraints may have restricted the use of transesophageal echocardiography (TEE). Our survey also suggests that hand-held or pocket echo devices were not widely adopted. This may be explained by the fact that these tools are relatively new and that many ICUs have high-end trolley ultrasound machines readily available (e.g. to guide CVC insertion).

One factor that may have influenced the importance of ultrasounds in the haemodynamic management of COVID-19 patients is the lack of availability of haemodynamic monitors. Echo evaluations usually take less than 30 min so that, pending proper cleaning, the same device can be used for the haemodynamic assessment of several patients. In contrast, haemodynamic monitors are dedicated to the monitoring of a single patient and are often used several consecutive days. Therefore, the shortage of haemodynamic monitors may have magnified the role of ultrasound techniques in this pandemic context. Another contributing factor is the ability to gather a lot of information from a single echo evaluation. Many respondents used echo not only to assess biventricular function but also to measure cardiac output, to predict fluid responsiveness and to detect lung B lines.

Cardiac output was frequently measured (69%). For many respondents (Fig. 4), and across the 3 main regions (Fig. 5), measurements were performed during echocardiographic evaluations. Otherwise, transpulmonary thermodilution was used by a significant number of respondents, with the exception of North America where uncalibrated pulse contour methods were used more often (Fig. 5). This is somewhat surprising given the fact that uncalibrated pulse contour methods are known to have limited accuracy and precision to measure cardiac output in septic shock

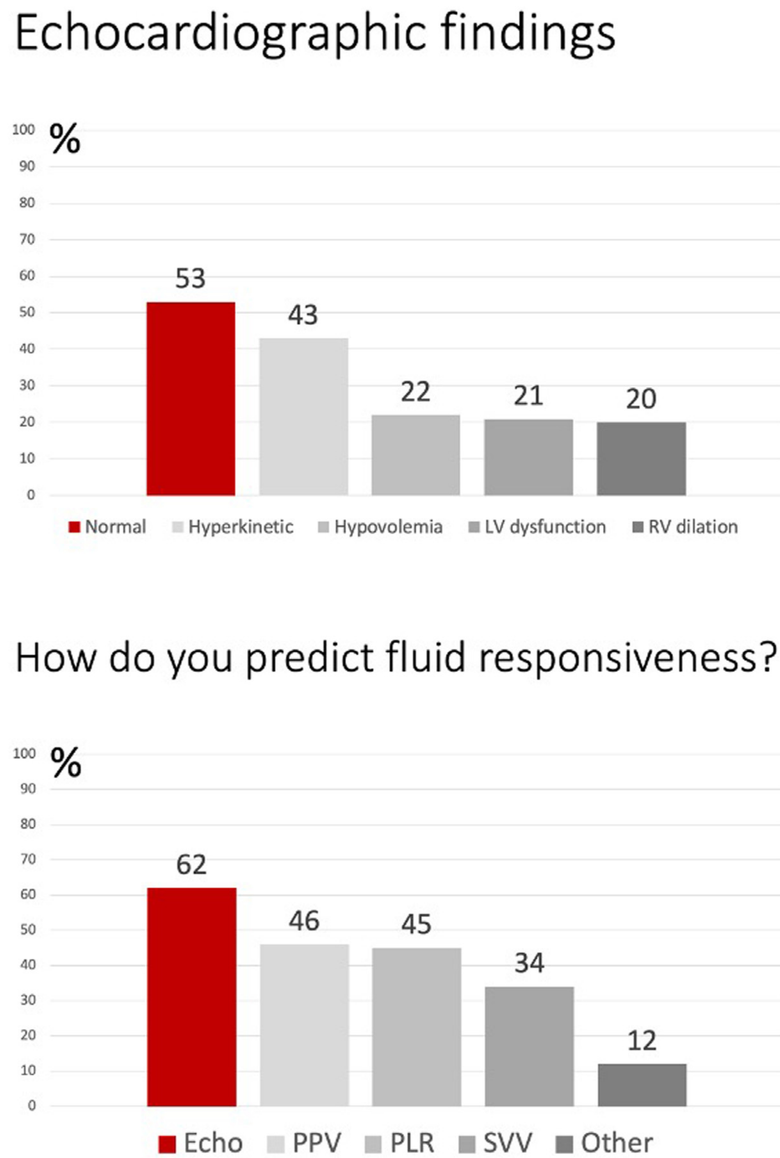
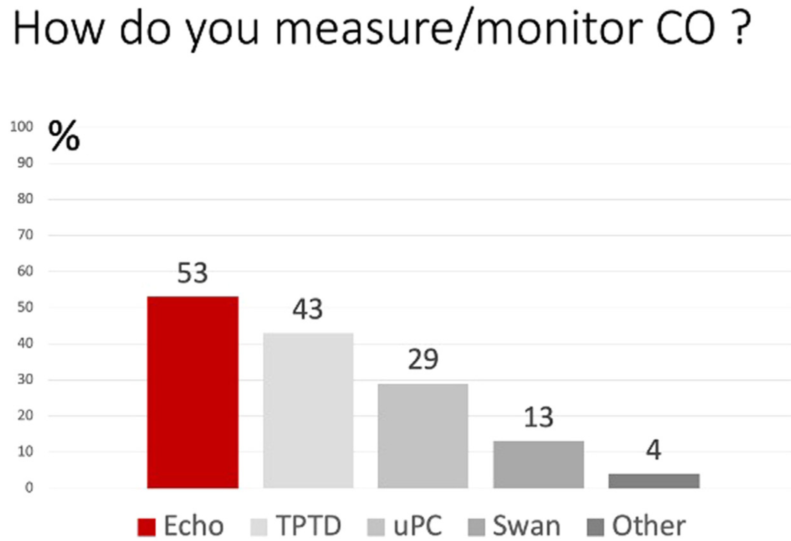


Fig. 3. Echocardiographic findings and methods used to predict fluid responsiveness.
LV, left ventricular; RV, right ventricular; PPV, pulse pressure variation; PLR, passive leg raising; SVV, stroke volume variation

[17], and their use is not recommended beyond the surgical population [18]. The Swan Ganz catheter was rarely used. Although pulmonary thermodilution remains a monitoring option in patients with septic shock [19,20], this finding is aligned with the global decline of this invasive tool [21] for which the new generation of intensivists did not receive much training. In addition, some clinicians may be reluctant to use a pulmonary artery catheter in the context of hypercoagulability and thrombo-embolic complications associated with COVID-19 [9,10].

The prediction of fluid responsiveness was adopted by a vast majority of respondents (84%). This finding contrasts with the results of a worldwide observational study suggesting that the prediction of fluid responsiveness is not routinely done in ICUs [22]. However, this study done 7 years ago may not reflect current practice anymore. The behaviour of our respondents is supported by recent studies showing outcome benefits when predicting fluid responsiveness in septic patients [23,24]. Echo was ranked #1 for the prediction of fluid responsiveness, globally and in the 3 main regions. It was mainly performed with a transthoracic probe (TTE). The prediction of fluid responsiveness with TTE requires the evaluation of the inferior vena cava (IVC) respiratory variations [25] or of the velocity-time integral (VTI) respiratory variations recorded at the level of the left ventricular outflow tract [26]. It is worth noticing that the fully automatic calculation of these variables is not available and that they have a limited sensitivity in patients ventilated with a low tidal volume for protective mechanical ventilation. Indeed, in this context, large IVC or VTI respiratory variations are highly suggestive of fluid responsiveness, but small variations cannot exclude it (false negative). The same limitation applies to PPV and stroke volume variation (SVV) that were also popular methods among our respondents (Fig. 3) [27]. The passive leg raising (PLR) manoeuvre is an alternative to TTE-derived variables, PPV and SVV to predict fluid responsiveness during protective mechanical ventilation [28]. It was used by 378 of the 835 respondents (45%) who predicted fluid responsiveness. The use of the PLR manoeuvre requires the simultaneous use of a fast response cardiac output monitoring system (typically a pulse contour technique) in order to capture transient changes in stroke volume or cardiac output during the manoeuvre [29].



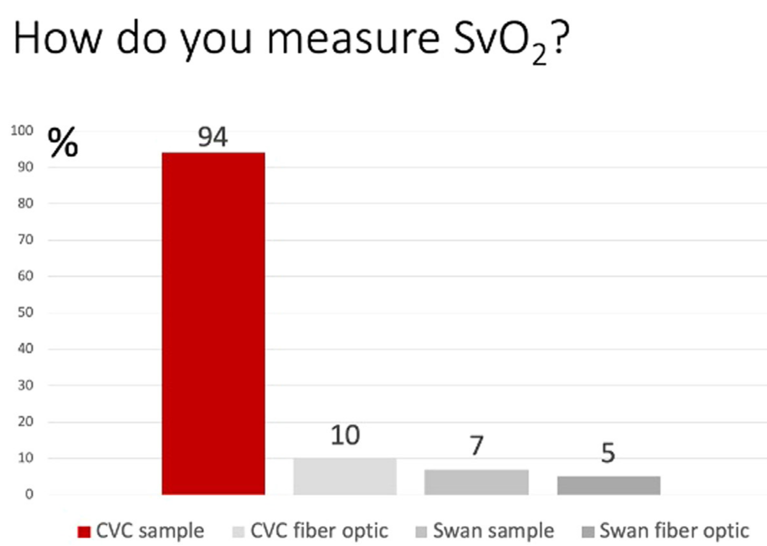


Fig. 4. Methods used to measure cardiac output (CO) and venous oxygen saturation (SvO_2).
TPTD, transpulmonary thermodilution; uPC, uncalibrated pulse contour; CVC, central venous catheter.

Venous oxygen saturation was very frequently measured from a CVC. In sedated patients, the 3 main determinants of venous oxygen saturation are haemoglobin, cardiac output and arterial oxygen saturation. Assuming haemoglobin stability, measuring venous oxygen saturation is a simple way to ensure that fluid restriction and PEEP do not decrease oxygen delivery. Both are used in an attempt to increase arterial oxygenation, but at the same time they are susceptible to decrease cardiac output. Therefore, at least from an oxygen delivery standpoint, the right volume status and the right PEEP level are those associated with the highest venous oxygen saturation [30]. This might be the reason why venous oxygen saturation was so popular among our respondents, but this remains a hypothesis. Indeed, our survey was a snapshot of current behaviours and was not designed to explain these behaviours.

The assessment of tissue oxygenation was almost exclusively based on clinical (e.g. capillary refill time) and biological (e.g. kidney function, lactates) evaluations. New techniques such as NIRS and video-microscopy were rarely used. They are probably considered as research tools [31,32] and one may imagine they were not available in many ICUs from many countries.

Our study has limitations. In addition to emails that are clearly targeted, we used social networks (LinkedIn, Twitter, WhatsApp) to invite clinicians answer the survey and share the link. Therefore, we were not able to control the number of clinicians who received the survey and hence to determine the percentage of respondents. Because the survey was built on a Google platform, it was not accessible from China and we were not able to include the feedback from Chinese doctors who have been involved in the pandemic from the very beginning. However, this is one of the largest surveys ever published in critical care [33] and we have been able to collect almost 900 responses from Europe and America, which are critical areas of the pandemic as well. Finally, this is a survey and not an audit nor an observational study. Therefore, the feedback gathered

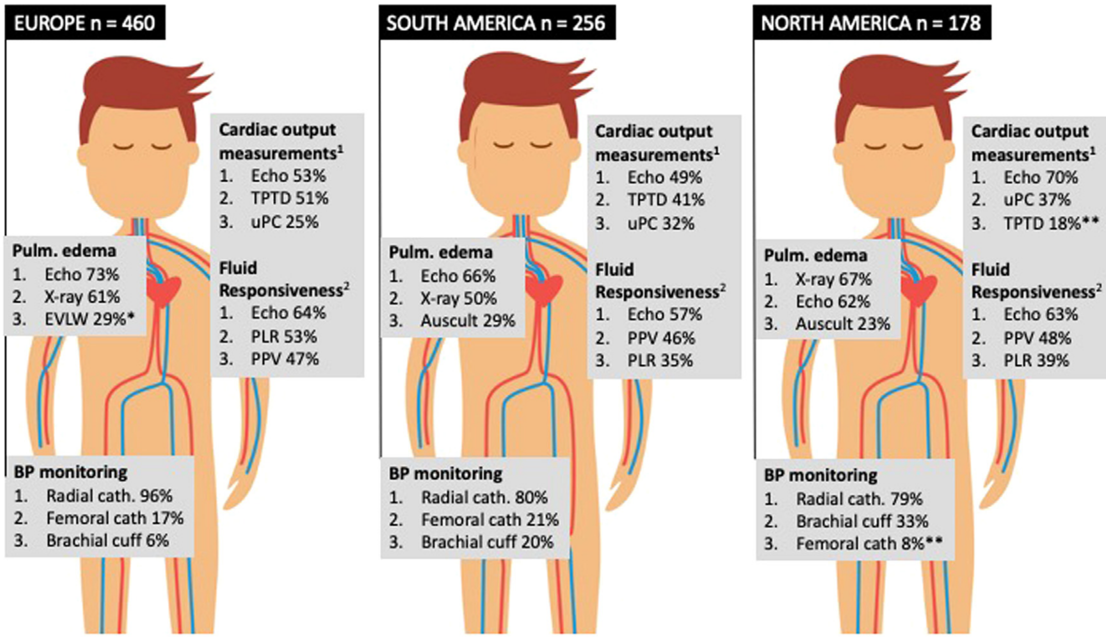


Fig. 5. Top 3 methods used to monitor blood pressure (BP), to measure cardiac output, to predict fluid responsiveness and to detect/quantify pulmonary oedema (Pulm. oedema) in the 3 main geographical areas.
TPTD, transpulmonary thermodilution; uPC, uncalibrated pulse contour; PPV, pulse pressure variation; PLR, passive leg raising; EVLW, extravascular lung water; cath.; catheter; Auscult., auscultation.
[1]Among respondents measuring or monitoring cardiac output
[2]Among respondents predicting fluid responsiveness
*more frequently used than in other regions
**less frequently used than in other regions

from clinicians reflects the perception they have of what is done or should be done in their unit, which may sometimes differ from reality [34]. In any case, our results remain of interest to understand where clinicians see value in haemodynamic monitoring tools and practice.

Conclusion

According to the 1000 intensivists and anaesthetists who sent back a valid questionnaire, vasopressor support was not uncommon in COVID-19 ICU patients. Several haemodynamic phenotypes were reported, highlighting the importance of echocardiography. Ultrasounds were used by many respondents, not only to assess cardiac function but also to predict fluid responsiveness and quantify pulmonary oedema. Venous oxygen saturation measurements from a central venous catheter were also reported to be common practice. Although we observed regional differences, current international guidelines were followed by most respondents.

Declaration of interests

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests:

FM is the founder and managing director of MiCo, a Swiss consulting and research firm (michardconsulting.com). MiCO does not sell any medical products and FM does not own any shares from any MedTech company. MLNGM is the president of the International Fluid Academy. He is a member of the medical advisory board of Pulsion Medical Systems and Serenno Medical, consults for Baxter, Maltron, ConvaTec, Acelity, Spiegelberg and Holtech Medical. GM is President-Elect of the Society of Critical Care Medicine (SCCM). TF is the president of the Swiss Society of Intensive Care (SGI-SSMI). SL is the president of the Brazilian Society of Critical Care (AMIB). FG is a member of the executive committee of the Portuguese Society of Intensive Care (SPCI). VPO is a member of the executive committee of the Portuguese Society of Anesthesiology (SPA) and he received honoraria for consulting from MSD and Octapharma. JMC is a member of the executive committee of the French Society of Anesthesia and Intensive Care (SFAR).

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Appendix A. Supplementary data

Supplementary material related to this article can be found, in the online version, at doi:https://doi.org/10.1016/j.accpm.2020.08.001.

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