Since January 2020 Elsevier has created a COVID-19 resource centre with free information in English and Mandarin on the novel coronavirus COVID-19. The COVID-19 resource centre is hosted on Elsevier Connect, the company's public news and information website.

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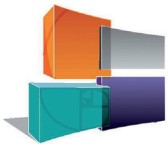

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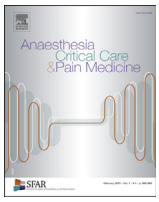

Editorial

Haemodynamic monitoring of COVID-19 patients: Classical methods and new paradigms

In the current issue of Anaesthesia Critical Care and Pain Medicine, Michard et al. [1] reported an international survey examining haemodynamic monitoring and management in COVID-19 intensive care patients [1]. The survey database was closed on May 16, 2020, after receiving 1000 valid questionnaires for analysis. Responses had come mainly from Europe (n = 460) and America (n = 434). Most responders were intensivists-anaesthetists (n = 920) but 80 were trainees. Among them, 23.7 % were physicians with over 10 years' experience working in the ICU.

Interestingly, when analysing the data, the authors found that the majority of COVID-19 ICU patients required vasopressor support, with certain changes in cardiac function patterns warranting echocardiographic monitoring. Moreover, most responders had followed the current recommendations on the use of echocardiography and the need to predict fluid responsiveness (FR) [2]. Regarding non-advanced haemodynamic monitoring, the survey reports that central venous catheters (CVCs) and invasive arterial monitoring were used by almost all respondents. CVCs were reported to be used for drug administration, measuring venous oxygen saturation, central venous pressure and determining the veno-arterial PCO_2 gradient [3].

On certain points, these results are both homogeneous and rational [4]. The fact that echocardiography was commonly used for COVID-19 patients is comprehensible, as the present non-invasive technique gives a complete cardiovascular evaluation [4]. However, the almost comparable percentage of incidences for both left ventricular (LV) systolic dysfunctions and hypovolaemia during echocardiography may question the valid mechanism of LV systolic dysfunctions. Similarly, focusing on applied physiology, another finding should be discussed in depth. Indeed, the fact that the majority of patients required vasopressor support is puzzling, even though we can agree that only a few patients could present both cardiogenic and distributive shocks [5,6]. Indeed, the key information to know regarding vasopressor requirements in COVID-19 ICU patients is the mean dose used. For instance, in the majority of cases, deep sedation [7], neuromuscular blocking agents and positive pressure ventilation induce relative hypovolaemia and hypotension [8], which impose modest doses of norepinephrine [9].

Compared to previous large international surveys published in 2015 [4,10], the current report shows that cardiac output monitoring and FR indexes have been largely used for the haemodynamic assessment of critically ill patients admitted for COVID-19. In 2015, haemodynamic status was assessed according to clinical criteria alone in more than two thirds of cases, despite the fact that numerous studies showed that arterial pressure, heart rate, skin mottling or any other clinical parameter led to poor evaluation of FR in 50% of cases [4,10]. In those two reports, cardiac output monitoring, pulse pressure variation and central venous pressure were used in fewer than 20 % of cases, whereas echocardiography was used in fewer than 10% of cases before deciding on fluid infusion. At the same time, the European Society of Intensive Care Medicine (ESICM) published detailed guidelines on circulatory shock and haemodynamic monitoring, which largely recommended the use of non-clinical tools such as echocardiography or transpulmonary thermodilution to assess the haemodynamic profile, in particular, FR [2]. The results presented in this issue of ACCPM by Michard and co-workers [1] shows a considerable use of cardiac output, which was monitored in 69% of cases, mainly by echocardiography and/or transpulmonary thermodilution (Figure 4).

These important changes in practices may be due to the global evolution in ICUs over the past 5 years, independently from the COVID-19 pandemic. It has been largely demonstrated that there is always a delay between the publication of international recommendations and their bedside implementation. The results of Michard et al. [1] may therefore reflect this delayed implementation of international guidelines [2]. A second explanation could be that the sudden, severe, massive SARS-CoV-2 pandemic may have induced specific concerns in ICU physicians' minds, leading to greater use of ICU resources, including haemodynamic monitoring and better application of the international recommendations. Obviously, the respective weight of the two phenomena cannot be differentiated by the present data. Moreover, in an electronic questionnaire, it may be tempting to give academic/theoretical responses, which do not truly reflect actual practices. Such remaining questions are interesting and argue for new surveys to be made, reporting raw data obtained from medical files, real data from echocardiographic exams, real consumption of transpulmonary or pulmonary artery catheters, numbers of SvO2s actually performed in biochemistry laboratories, etc... It would also be interesting to compare haemodynamic practices between confirmed COVID-19 cases and non-COVID-19 patients.

A second important result is that, in the present survey, COVID-19 does not seem to induce new patterns of haemodynamic failure (Figure 3) [1]. About 50% of patients do not have significant haemodynamic alteration and the most frequent haemodynamic profile is a classical hyperdynamic state, related to systemic

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inflammation induced by SARS-CoV-2 infection. In the present report [1], systolic ventricular dysfunction was rare (around 20% of cases), which is consistent with another recent report [11]. Nevertheless, cardiac dysfunction cannot be restricted merely to severe systolic dysfunction. Indeed, occult diastolic dysfunction (not studied in the present report) appears common [11] and may have a significant impact, especially in the ventilator weaning period. Finally, in this report, the echocardiographic assessment of FR and/or definition of hypovolaemia are not precisely detailed. The only way to be sure that the patient is hypovolaemic is to demonstrate a 10 to 15% increase in CO/SV/subaortic VTI after conventional fluid challenge, passive leg-raising test or minifluid challenge [2]. "Simple" tools like respiratory-induced variations in diameter of the inferior vena cava are very popular, but have limited accuracy in predicting FR due to numerous false positive or false negative cases, both in ventilated and non-ventilated ICU patients [12–15]. Therefore, defining hypovolaemia or FR with echocardiography is of paramount importance and the choice of index could considerably influence the number of responders/non-responders.

Lastly, considering COVID-19 patients from a pathophysiological viewpoint, various studies have demonstrated the complex interplay between the renin-angiotensin-aldosterone-system (RAAS) and SARS-CoV-2. In this respect, SARS-CoV-2 uses the host protein angiotensin-converting enzyme-2 (ACE2) as a co-receptor to gain intracellular entry into the lung [16]. Now, it is a known fact that the primary role of ACE2 is to efficiently degrade Angiotensin II (ANGII) [17]. Consequently, the loss of ACE2 shifts the system to an overall higher ANGII level due to ACE2's impaired ability to degrade it [18]. ANG II is a well-known potent vasopressor agent which could be used in conjunction with other vasopressors to stabilise critically ill patients during refractory septic shock and reduce catecholamine requirements [19]. Interestingly, Liu et al. recently reported that the circulating levels of ANGII were significantly higher in patients with COVID-19 than in healthy controls [20]. The present fact may explain the relatively spectacular haemodynamic stability of patients with COVID-19, even in deeply sedated mechanically ventilated patients, with a tendency towards a hypertensive profile during the weaning stage [18].

Over the last two decades of the 21st century, it has not been clear which method of haemodynamic monitoring to use with critically ill patients. However, our understanding of these subjects is constantly evolving, and several certainties have emerged regarding the central role of CO monitoring, echocardiography and FR assessment. Nowadays, evidence-based medicine (EBM) is especially necessary to demonstrate the efficacy of new techniques as the financial side of health delivery is under increasing scrutiny. However, the reductionist tradition of EBM is probably inappropriate when applied to a complex clinical disease like COVID-19, where several organs and new pathological concepts are involved (multimorbidity). In the present context, a clinical survey at least has the merit of reflecting a broad image of experienced physicians' clinical practices.

Conflicts of interest

The authors have no conflicts of interest.

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