Dear Editor,

Peripheral VA-ECMO is used as a temporary cardiac support in stage D and E of cardiogenic shock [1]. To prevent lower limb ischemia due to the occlusive effect of the arterial cannula in the femoral artery, a limb reperfusion cannula is usually placed in the ipsilateral superficial femoral artery [2]. A few published case reports suggest that angiography through the reperfusion cannula is efficient to detect and monitor the treatment of the arterial adverse events during VA-ECMO [3, 4]. This procedure has never been correctly formalized and evaluated.

This monocentric study is a prospective evaluation of a strategy to prevent lower limb complications during VA-ECMO with a systematic arterial angiography through the reperfusion line, on VA-ECMO implantation and when limb ischemia is suspected, in addition to continuous lower-limb near infrared spectroscopy (NIRS) monitoring (https://clinicaltrials.gov/ct2/show/NCT03910062). When performed in the ICU, a digital mobile X-ray device was used with the panel sensor placed underneath the patient’s leg to ensure the of visualization of both the superficial femoral and the popliteal arteries. A 10 ml to 20 ml dose of iodinated contrast was injected through the three-way stopcock towards the reperfusion cannula, followed by the X-ray acquisition. Lower limb tissue oxygenation was continuously monitored by NIRS (Masimo-Root® with O3®-Regional Oximetry). Limb ischemia was defined as a NIRS value < 50% on the ipsilateral limb and/or a differential between lower limbs >15% [5]. The primary outcome was the incidence of severe lower limb ischemia (ischemia leading to a surgical intervention, functional sequelae, extremities necrosis or compartment syndrome) at day 60.

From June 2019 to April 2020, 39 consecutive patients were included at Nancy’s Teaching Hospital. Patients’ characteristics and outcomes are reported in Table 1. Indication for VA-ECMO was refractory cardiogenic shock (n = 14) or refractory cardiac arrest (n = 25). Eleven (28%) patients were cannulated with a percutaneous ultrasound-guided technique and 28 (72%) by
surgical cut-down. The high rate of refractory cardiac arrest explains the high rate of surgical cut-downs as the surgical technique being preferred at our center for extracorporeal cardiopulmonary resuscitation. The reperfusion cannula was a 6F (AVANTI®+, Cordis, USA) sheath introducer (ultrasound-guided percutaneous insertion or under visual control in case of surgical cut-down).

Forty-three angiographies were performed during the study period. Thirty-seven angiographies were performed at VA-ECMO implantation (not performed = 2). Six adverse events related to the reperfusion cannula were detected at VA-ECMO implantation: four misplacements (in the deep femoral artery or the femoral vein), one reperfusion cannula kinking and one hemorrhage secondary to an arterial puncture (Fig. 1). The detection of reperfusion cannula abnormalities at VA-ECMO implantation allowed a prompt intervention without subsequent limb ischemia. The four misplacements occurred with the surgical technique under high doses of norepinephrine.

During the run of VA-ECMO, nine ischemic events were suspected based on NIRS criteria. The cause for limb ischemia was obvious in three cases (e.g. reperfusion cannula thrombosis) and a bedside angiography was performed for the six remaining. The angiographic findings were: two thrombosis, one vasospasm, one with both and two normal. One patient (arterial thrombosis on angiography) ultimately required an amputation. The remaining ischemic events were all resolutive with a medical treatment (e.g. vasodilators, ECMO flow increase). There was no complication recorded due to the angiography procedure.

| Table 1 Characteristics of the study population and outcomes |
|---------------------------------------------------------------|
| Demographic characteristics | n = 39 |
| Age, years | 58 (46, 64) |
| Male sex, n (%) | 30 (77%) |
| BMI (kg/m²) | 28 (24, 29) |
| Simplified acute physiological score 2 | 74 (56, 92) |
| SOFA score at admission | 13 (10, 14) |
| Comorbidities, n (%) | |
| Chronic kidney failure | 2 (5%) |
| Diabetes | 5 (13%) |
| Occlusive peripheral arterial disease | 4 (10%) |
| Long-term antiplatelet therapy | 8 (21%) |
| History of smoking > 10 pack-years | 17 (44%) |
| VA-ECMO indication | |
| E-CPR (OHCA and IHCA) | 24 (62%) |
| Refractory Cardiogenic Shock | 15 (38%) |
| Canulation technique | |
| Percutaneous canulation | 11 (28%) |
| Surgical approach | 28 (72%) |
| Primary outcome | |
| Severe lower limb ischemia (amputation, fasciotomy or surgical intervention) | 1 (3%) |
| Secondary outcomes | |
| Lower limb ischemia (NIRS < 50% and/or differential > 15%) | 9 (23%) |
| ICU mortality, n (%) | 20 (51%) |
| Duration of ICU stay, days | 10 (5, 18) |
| Duration of hospital stay, days | 17 (7, 42) |
| Renal replacement therapy during the ICU stay | 15 (39%) |

Data are presented as the median [Q1, Q3] or number of patients with the percentage in parentheses, as appropriate.

BMI: body mass index, SOFA score: sequential organ failure assessment score, OHCA: out-of-hospital cardiac arrest, IHCA: in-hospital cardiac arrest.
In conclusion, bedside angiography through the lower limb reperfusion is a safe and efficient procedure in the management of arterial complications during VA-ECMO. Combined with continuous NIRS monitoring, this technique allows a fast diagnosis of vasospasm or thrombosis when ischemia is suspected. Performed at VA-ECMO implantation, it confirms that the reperfusion cannula is properly positioned in the superficial femoral artery.
Acknowledgements
None.

Authors’ contributions
MK drafted the manuscript and participated in the design of the study. AK participated in the design of the study, performed the statistical analysis and helped to draft the manuscript. MM, JPM and BL participated in the design and coordination of the study and helped to draft the manuscript. All authors read and approved the final manuscript.

Funding
This research received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors.

Availability of data and materials
The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request.

Declarations

Ethics approval and consent to participate
The protocol was submitted to and validated by an ethics committee (Comité d’Ethique CHRU de Nancy, Ref 2019/215). Considering that post cannulation angiography is a standard of care procedure in our unit, this research is classified, according to French law, MR00-3: “Research in the Field of Health Without Collection of Consent”. All patients were informed that their medical data were anonymously included in the study. Patients had the possibility not to participate in the study.

Consent for publication
Not applicable.

Competing interests
Pr Kimmoun received speaker’s honoraria from Aspen and Aguettant. Pr Levy received speaker’s honoraria from Getinge and Abiomed. The other authors declare no conflict of interest related to the submitted paper.

Author details
1 CHRU de Nancy, Médecine Intensive et Réanimation Brabois, Université de Lorraine, Nancy, France. 2 CHRU de Nancy, Service de Chirurgie Cardiaque, Université de Lorraine, Nancy, France. 3 CHRU de Nancy, Médecine Intensive et Réanimation Brabois, INSERM U1116, Université de Lorraine, Nancy, France.

Received: 8 July 2021 Accepted: 24 July 2021
Published online: 31 July 2021

References
1. de Chambrun MP, Donker DW, Combes A. What’s new in cardiogenic shock? Intensive Care Med mai. 2020;46(5):1016–9.
2. Bonicollini E, Martucci G, Simons J, Raffa GM, Spina C, Coco VL, et al. Limb ischemia in peripheral veno-arterial extracorporeal membrane oxygenation: a narrative review of incidence, prevention, monitoring, and treatment. Crit Care Lond Engl. 2019;23(1):266.
3. Gordon C, Ghodsizad A, Brehm C, Koerner MM, El-Banayosy A. Improved angiographic findings of superficial femoral artery after verapamil injection into the reperfusion cannula of a patient on peripheral venoarterial ECMO. Heart Surg Forum. 2014;17(5):E261-262.
4. Arroyo D, Bendjelid K, Robert-Ebadi H, Rigamonti F, Siegenthaler N, Giraud R. Suspected Arterial Vasospasm in Femoro-Femoral Venoarterial Extracorporeal Life Support. ASAIO J. 2017;63(3):e35-8.
5. Patton-Rivera K, Beck J, Fung K, Chan C, Beck M, Takayama H, et al. Using near-infrared reflectance spectroscopy (NIRS) to assess distal-limb perfusion on venoarterial (V–A) extracorporeal membrane oxygenation (ECMO) patients with femoral cannulation. Perfusion. 2018;267659118777670.

Publisher’s Note
Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.

Ready to submit your research? Choose BMC and benefit from:
• fast, convenient online submission
• thorough peer review by experienced researchers in your field
• rapid publication on acceptance
• support for research data, including large and complex data types
• gold Open Access which fosters wider collaboration and increased citations
• maximum visibility for your research: over 100M website views per year

At BMC, research is always in progress.
Learn more biomedcentral.com/submissions