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Research paper

Effects of extracorporeal membrane oxygenation pump flow, backflow cannulae, mean arterial blood pressure, and pulse pressure on Doppler-derived flow velocities of the lower limbs in patients on peripheral veno-arterial extracorporeal membrane oxygenation: A pilot study



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ABSTRACT

Background: Reported rates of limb ischaemia on peripheral veno-arterial extracorporeal membrane oxygenation (pVA ECMO) vary from 1–52%.

Objectives: Primary: To explore (i) the feasibility for appropriately trained intensive care unit staff to measure Doppler derived flow velocities of the lower limbs for patients on pVA ECMO; and (ii) whether these measurements are clinically useful. Secondary: explore the relationship between ECMO pump flow, backflow cannulae (BFC) properties, mean arterial blood pressure (MAP), and pulse pressure on flow velocities.

Method: Inclusion criteria: age > 18 years, on pVA ECMO > 24 hours. Exclusion criteria: any guardianship limitations and patients without a BFC.

Serial patients receiving pVA-ECMO over a 10 month period had Doppler derived flow velocities of the lower limbs sampled. Simultaneously, other pertinent parameters were recorded. 80% inclusion was considered clinically feasible. Study personnel were asked for feedback regarding the ease and usefulness of studies.

Results: 15 of 17 patients were included: 88% inclusion. Mean peak systolic velocity (PSV) in the cannulated limb was 31 ± 29 cm/s in the dorsalis pedis (DP) and 27 ± 18 cm/s posterior tibial (PT). Similar flows were recorded in the non-cannulated limbs (DP 34 ± 29 cm/s, PT 44 ± 36 cm/s; $P > 0.05$). PSV was positively correlated with pulse pressure in cannulated and non-cannulated limbs respectively ($r = 0.63$, $P < 0.05$; $r = 0.67$ and $P < 0.05$). There was no significant correlation between PSV and MAP. ECMO pump flow and BFC were negatively correlated with PSV ($r = -0.51$, $P < 0.05$; $r = -0.43$, $P < 0.05$).

Conclusion: It is generally feasible for ICU staff to measure flow velocities of the lower limbs for patients on pVA ECMO. It remains unclear how clinically useful these measurements are. Doppler derived flow velocities of arteries of the lower limbs of patients on pVA ECMO appear different to non-ECMO patients. PSV in the lower limbs of patients on pVA ECMO seems to be more related to pulse pressure than to other haemodynamic parameters.

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1. Background

Extracorporeal membrane oxygenation (ECMO) provides life support for patients with refractory respiratory and/or cardiac failure and is being utilised more widely with the development of advanced technologies and exposure through events such as the 2009 influenza A (H1N1) pandemic.¹ However, the application of this lifesaving therapy does not come without potential complications.² One serious complication of peripheral veno-arterial (pVA) ECMO via the femoral vessels is limb ischaemia that may sometimes lead to the necessity for fasciotomy or amputation. Reported rates of limb ischaemia on pVA ECMO vary. Roussel et al.'s 2013 review² reported a range of 4.4–19% for six included studies, and von Segesser et al.'s 2016 review¹ reported a range from 11 to 52% from eight included studies and also reported amputation rates from 1 to 10%.

Causes for limb ischaemia on pVA ECMO include pre-ECMO hypo-perfused states, vasopressor requirements, effects of ECMO cannulation (e.g., placement of large French gauge cannula in the femoral artery which may then necessitate the placement of a backflow cannulae (BFC) to ensure perfusion of the distal limb), venous stasis and increased venous pressure resulting in decreased perfusion pressure to the limb, and actual or attempted insertion of non-ECMO devices in the femoral vessels (e.g., intra-aortic balloon catheter or intra-arterial blood pressure monitoring catheters).^{1,2} The Extracorporeal Life Support Organization that collects data from contributing sites around the globe in its 2017 report indicated a limb ischaemia rate of 1%,³ although this is likely to be an underestimate as this complication has been recently added to the reporting variables and relies on hospitals self-reporting the incidence. According to the study site ECMO database, for 2015, the rate of lower limb ischaemia on pVA ECMO was approximately 7.5%.

This rate was considered relatively high, despite being consistent with reported rates² of limb ischaemia in other ECMO centres. The aim of this pilot study therefore was to explore the relationships between the various factors that might contribute to lower limb ischaemia on pVA ECMO patients.

2. Objectives

The primary goals of this pilot study were to explore (i) the feasibility for intensive care unit (ICU) staff [ICU clinical nurse consultant (CNC) and ICU echocardiography fellow] to measure Doppler-derived flow velocities of the lower limbs for patients on pVA ECMO and (ii) whether Doppler-derived flow velocities of the lower limbs are clinically useful. Secondary goals were to explore the relationship between ECMO pump flow, properties of the BFC, mean arterial blood pressure (MAP), and pulse pressure (measurement of PP) on flow velocities.

3. Methods

Ethics approval was granted by the institution's ethics committee. Written informed consent was not required as it involved a low negligible risk non-interventional patient assessment. Mitigation of risk due to identifying patients was achieved through de-identification of patient data. The study centre is a 20-bed adult level three⁴ tertiary referral and teaching unit in Australia. It is a state centre for cardiopulmonary transplantation and ventricular assist devices and provides an ECMO programme and retrieval services. Serial patients receiving pVA ECMO were sampled over a 10-month period. This time period for data collection was selected based upon historical data, including recent trends, and allowing for expected, missed, or lost data to provide a minimum sample of 10. Doppler-derived flow velocities of the lower limbs were

sampled (1–4 times) on different days in different circumstances to ensure a representative sample. The inclusion criteria for this study were patients 18 years and above and on VA ECMO for more than 24 h. Exclusion criteria were patients under guardianship limitations, patients receiving ECMO via central or subclavian cannulation, and patients who did not receive a BFC.

The study design directed that Doppler-derived flow velocities of the lower limbs in patients on pVA ECMO were measured by the ICU CNC and the ICU echocardiography Fellow, usually together, but individually according to circumstances, using suitable equipment that was available at the time. Ultrasound flow velocity studies were generally conducted either with the Fuji Film SonoSite® and L25 probe or the Philips iE33® and L11-3 probe based on the methods described by Holland et al.⁵ and Gill.^{6,7} The ICU echocardiography Fellow was trained via a postgraduate course, ongoing practical supervised development within their Fellowship year, and by attendance at the Vascular Ultrasound Clinic for specific hands on training in this technique. The ICU CNC undertook a 2-day echocardiography course and additional hands on training employing this ultrasound technique from the ICU echocardiography fellow. Peak systolic flow velocities (PSVs) in the dorsalis pedis (DP) and posterior tibial (PT) arteries of patients were recorded. Simultaneously, ECMO flow, backflow cannula flow, arterial blood pressure, heart rate, and lower limb regional oximetry were recorded.

To determine feasibility related to study procedures, the number of patients suitable for inclusion and the number actually included were recorded considering a greater than 80% inclusion as clinically feasible. In addition, at conclusion of the study, the personnel

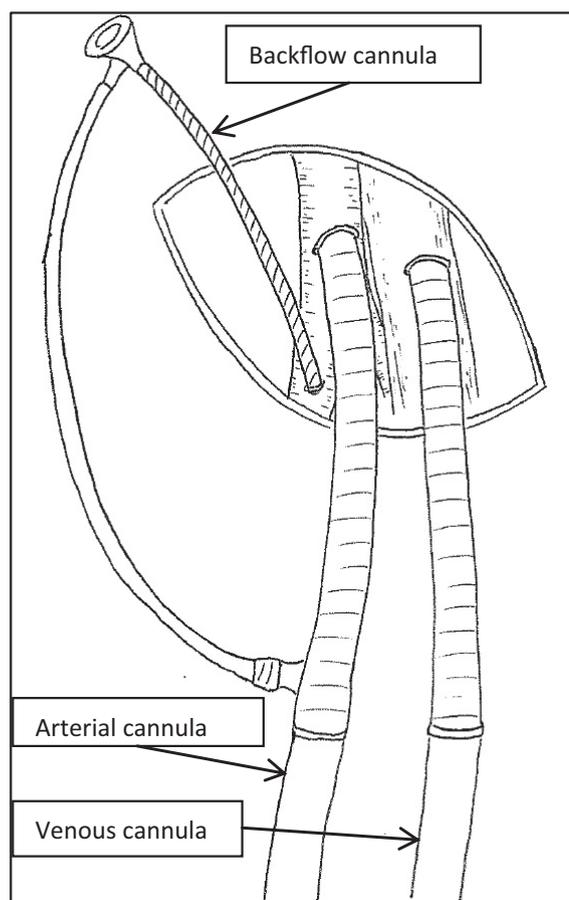


Fig. 1. Sheath placed in superficial femoral artery as the backflow cannula (by Y Kawanishi).

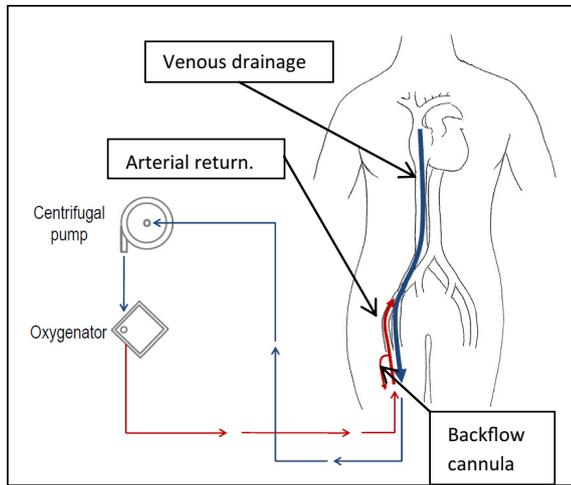


Fig. 2. Standard pVA ECMO configuration at study centre (by Y Kawanishi). ECMO = extracorporeal membrane oxygenation; pVA = peripheral veno-arterial.

conducting the flow velocity studies were asked for informal oral summary feedback regarding whether their impression was that their ultrasound studies within the ICU were easy to perform and whether these might influence clinical management. Data collected included demographic information such as gender, age, severity of illness score (APACHE 111), diagnosis category, and medical admission history. Information related to ECMO provision was also gathered: cannulae size, location, and possible related complications. Additional outcome data included mortality rates, length of stay, and ventilator days.

The pVA ECMO at the study centre was provided utilising Getinge Maquet® venous drainage HLS cannulae with French sizes ranging from 19 to 25 and Getinge Maquet® Arterial return heart lung support (HLS) cannulae, sizes ranging from 15 to 21, in conjunction with an Arrow® French Size 7 Super Arrow-Flex Percutaneous Sheath placed in the superficial femoral artery as the backflow cannula (See Fig. 1). The ECMO pump utilised was either the Getinge Maquet® centrifugal pump in conjunction with the Maquet permanent life support (PLS)-i oxygenator or the Getinge Cardiohelp® centrifugal pump in conjunction with the HLS oxygenator (See Fig. 2). The pVA ECMO was managed according to the institution's standard protocol which involved the employment of the single caregiver model in which a trained and accredited ECMO nurse provided the bedside care of the patient and ECMO with additional support and medical management from other members of the ECMO team.

Table 1
Demographic data.

Variable	Result (N = 15)
Gender	
Male, n (%)	9 (60)
Female, n (%)	6 (40)
Age (y), mean (±SD)	47 ± 18
Height (cm), mean (±SD)	174 ± 6
Weight, mean (±SD)	83 ± 27
BSA, mean (±SD)	1.98 ± 0.3
APACHE 111, mean	69.1
Admission category	
ECPR n (%)	7 (47)
Graft failure after heart transplant n (%)	3 (20)
Post cardiomy heart failure, n (%)	2 (13)
Cardiogenic shock, n (%)	2 (13)
Heart failure (bridge to VAD), n (%)	1 (7)

BSA = body surface area; ECPR = ECMO cardiopulmonary resuscitation; SD = standard deviation; VAD = ventricular assist device.

Table 2
Patient and ECMO circuit parameters.

Variable	Result (N = 25)
Mean arterial pressure mmHg, mean (±SD)	72.5 ± 8.9
Pulse pressure mmHg, mean (±SD)	32.5 ± 19.3
Cannulated lower limb regional oximetry %, mean (±SD)	80.3 ± 8.5
Non-cannulated lower limb regional oximetry %, mean (±SD)	79.1 ± 8.8
4 th hour ECMO blood pump flow L/min, mean (±SD)	3.59 ± 0.48
24 th hour ECMO blood pump flow L/min, mean (±SD)	3.42 ± 0.62
Time of testing ECMO blood pump flow L/min, mean (±SD)	2.93 ± 0.83
Backflow cannula flow mLs/min, mean (±SD)	150.5 ± 38.9
DP systolic velocity of cannulated lower limb cm/sec, mean (±SD)	33.4 ± 30.6
DP systolic velocity of non-cannulated lower limb cm/sec, mean (±SD)	35.5 ± 32.3
PT systolic velocity of cannulated lower limb cm/sec, mean (±SD)	31.3 ± 30.4
PT systolic velocity of non-cannulated lower limb cm/sec, mean (±SD)	44.4 ± 35.9

DP = dorsalis pedis; ECMO = extracorporeal membrane oxygenation; PT = posterior tibial; SD = standard deviation.

Table 3
Outcome parameters.

Variable	Result (N = 15)
ECMO days mean (±SD)	6.8 ± 5.4
Ventilator days mean (±SD)	10.5 ± 8.9
ICU days mean (±SD)	18.1 ± 15.1
Hospital days, mean (±SD)	51 ± 71.5
Survival	
ECMO, n (%)	11 (73)
ICU, n (%)	9 (60)
Hospital, n (%)	8 (53)

ECMO = extracorporeal membrane oxygenation; ICU = intensive care unit; SD = standard deviation.

Table 4
Survival for ECPR category.

Variable	Result (N = 7)
Survival of ECPR to:	
ECMO de-cannulation, n (%)	3 (43)
ICU discharge, n (%)	2 (29)
Hospital discharge, n (%)	2 (29)

ECMO = Extracorporeal membrane oxygenation; ECPR = ECMO cardiopulmonary resuscitation; ICU = intensive care unit.

Table 5
ECMO cannulae employed.

Venous cannulae French Size	N = 15	Arterial cannulae French Size	N = 15
19, n (%)	1 (7)	17, n (%)	8 (53)
21, n (%)	4 (27)	19, n (%)	3 (20)
23, n (%)	6 (40)	21, n (%)	1 (7)
24, n (%)	1 (7)	Not recorded	3 (20)
25, n (%)	1 (7)		
Not recorded	2 (13)		

ECMO = extracorporeal membrane oxygenation.

Analysis included descriptive statistical techniques to evaluate the effect of the ECMO flow, backflow cannula, MAP, and PP on the flow velocities and provide pertinent Pearson correlations with significance threshold of $p < 0.05$. Continuous data were analysed using means and standard deviation (or medians with interquartile range) based on normality of data sets. Statistical analysis was conducted using IBM® SPSS® Statistics, version 23, statistical software.

4. Results

During the study period, 37 patients received ECMO for cardiac support. Ten of them received cannulation configuration involving central or subclavian techniques. Another six patients received ECMO for less than 24 h, and four did not have a BFC. Two patients were not included due to absence of study personnel or unavailability of study equipment. The remaining 15 patients were included in the study. Twenty-five data sets from these 15 patients were obtained from September 2015 to July 2016. Fifteen out of a total of 17 patients were included in the analysis. This provided an inclusion rate of 88%. The informal oral summary feedback from study personnel regarding their impressions indicated that the procedures were generally achievable; however, they were sometimes time consuming and conflicted with other priorities.

Demographic data, including admission category, of the study group are presented in Table 1. Patient, ECMO circuit, and lower limb Doppler-derived mean peak velocity characteristics are

presented in Table 2 and expressed in standard measures with mean and standard deviation provided. Outcome parameters such as ECMO days, ventilator days, hospital length of stay, and survival are presented in Table 3 and expressed in either mean and standard deviation or number and percentage as appropriate. Table 4 displays survival data for the ECMO cardiopulmonary resuscitation (ECPR) subgroup and Table 5 details the cannulae that were used.

Doppler-derived flow velocities indicated that the mean peak velocity in the cannulated limb was 31 ± 29 cm/s in the DP and 27 ± 18 cm/s in the PT. Similar flows were recorded in the non-cannulated legs (DP 34 ± 29 cm/s, PT 44 ± 36 cm/s; $P > 0.05$). PSV was positively correlated (using Pearson correlation) with PP in cannulated and non-cannulated limbs, respectively ($r = 0.63$, $P < 0.05$ and $r = 0.67$, $P < 0.05$, respectively). There was no significant correlation between PSV and MAP. ECMO pump flow and backflow cannula flow were negatively correlated (using Pearson correlation) with PSV ($r = -0.51$, $P < 0.05$; $r = -0.43$, $P < 0.05$). Lower limb regional oximetry was similar between both limbs (cannulated $80.3 \pm 8.5\%$, non-cannulated $79.1 \pm 8.8\%$; $P > 0.05$).

5. Discussion

5.1. Main findings

This pilot study demonstrated overall feasibility for appropriately trained ICU staff to measure Doppler-derived flow velocities of the lower limbs for patients on pVA ECMO. However, there are various difficulties such as prioritising this task on top of pre-existing workload and fit within role expectations. Some ultrasound studies of flow velocities of the lower limbs can also be difficult to locate especially for patients on pVA ECMO who have little or no arterial pulsatility, and the flow pattern generated is largely from the centrifugal ECMO blood pump in combination with the patient's haemodynamic profile (See Figs. 3 and 4 for depiction of flow velocity studies in pulsatile and non-pulsatile states). It can be time consuming to locate and measure the flow velocity in some circumstances, especially since the vessels' diameters may be limited to millimetres.

The usefulness of Doppler-derived flow velocities of the lower limbs is also difficult to clinically determine. As these studies are sometimes difficult and require a high level of skill, ideally highly trained and practiced vascular sonographers should conduct these studies, however that presents logistic challenges. In practice, it was found where Doppler velocity was unable to be determined and there were other clinical signs of ischaemia, a referral was made for further review and possible intervention by appropriate experts. Hence, ICU staff-conducted ultrasound of lower limb vessels might be a useful screening strategy, identifying the need for more detailed limb assessment using other techniques. None of the patients included in this study required any medical intervention for ischaemia, e.g. fasciotomy. However, non-study patients did require interventions varying from fasciotomy, to insertion of BFC, to change of ECMO configuration. The non-study patients experiencing limb ischaemia highlighted the significance of being able to call upon a battery of assessment tools when required.

The relationship between PP and measured PSV in the DP and PT in both cannulated and non-cannulated lower limbs demonstrated a positive Pearson correlation ($P < 0.05$). This is in keeping with the expected physiology of pVA ECMO where as cardiac function improves and pulsatility increases, the patient is less dependent on the ECMO pump for the equivalent cardiac output, and this resultant increased pulsatility and increased peak velocity could be found on Doppler-derived flow studies of the lower limb arteries. Conversely as ECMO pump flow increased, BFC flow increased and PSV decreased. Interestingly, the mean BFC flow of 150 ± 38.9 mL/s

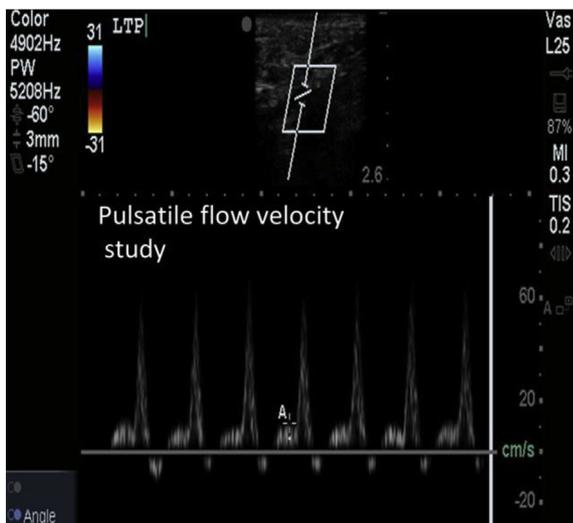


Fig. 3. A Doppler-derived flow velocity study demonstrating pulsatile flow in the PT. PT = posterior tibial.

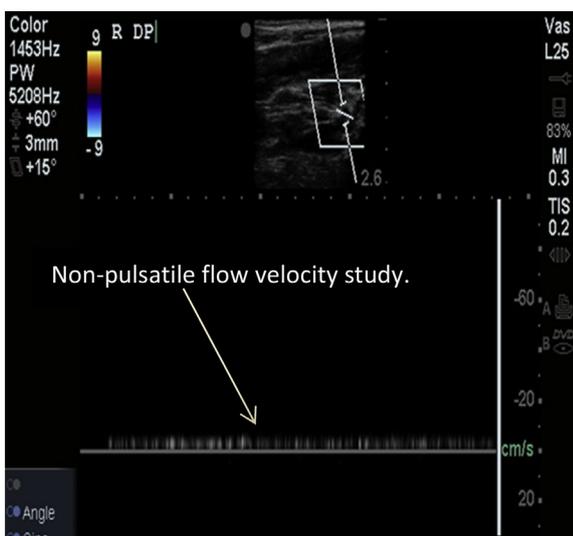


Fig. 4. A Doppler-derived flow velocity study demonstrating continuous flow in the DP (i.e., non-pulsatile perfusion). DP = dorsalis pedis.

 ST VINCENT'S HOSPITAL SYDNEY ECMO Lower Limb Observations		MRN		SURNAME									
		GIVEN NAME(S)											
		DOB	SEX	AMO	WARD/CLINIC								
(Please enter information or affix Patient Information Label)													
Type of ECMO (circle): Central / Peripheral VA / VV / VPA Drain Cannulae (circle): R Atrial / R Fem V / L Fem V / RIJ / Other: _____ Return Cannulae (circle): Aorta / L Fem / R Fem / IJ / PA Other: _____ Back Flow Cannula (circle): RSFA LSFA													
DATE:	Time:	1100	1200	1300	1400	1500	1600	1700	1800	1900	2000	2100	2200
Back Flow Cannula mLs/min:													
Regional Saturation of Oxygen rSO ₂ (Mid calf measurement unless otherwise advised)		Right											
		Left											
Mid Calf Measurement (cm)		Right											
		Left											
Palpation Calf	S Soft F Firm H Hard	Right											
		Left											
Palpation Thigh	S Soft F Firm H Hard	Right											
		Left											
Ankle Flexion	A Active P Passive N Nil	Right											
		Left											
Knee Flexion	A Active P Passive N Nil	Right											
		Left											
PULSES Dorsalis Pedis	S Strong (palpable) W Weak (palpable) Dp Doppler Pulsatile Dc Doppler Continuous Flow A Absent	Right											
		Left											
Posterior Tibialis	S Strong (palpable) W Weak (palpable) Dp Doppler Pulsatile Dc Doppler Continuous Flow A Absent	Right											
		Left											
Colour (Check hip to toe)	N Natural P Pale C Cyanotic M Mottled W White	Right											
		Left											
Temperature (Check hip to toe)	H Hot W Warm C Cool Cd Cold	Right											
		Left											
Capillary Refill	< 3 secs > 3 secs	Right											
		Left											
Pain Score (early sign)	0 - 10 (if awake) Y or N (if sedated)	Right											
		Left											
Comments:													

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ECMO LOWER LIMB OBSERVATIONS

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Page 1

Fig. 5. ECMO limb observation chart. ECMO = extracorporeal membrane oxygenation.

min appeared to be reasonably similar with other volumetric flow studies of the superficial femoral artery for non-ECMO normal subjects (152 ± 66 mLs/min– 196 ± 69 mLs/min).^{5,8} There was also no significant difference between the regional oximetry applied on both lower limbs. There were no other significant relationships to note between the flow velocities, haemodynamic, and ECMO pump parameters.

5.2. Comparison with other studies

The measured ultrasound peak velocities in this study (DP 33.4 ± 30.6 cm/s; PT 31.3 ± 30.4) appear to be significantly different to other reported results in non-ECMO patients. For example, Holland et al. report peak velocities for DP at 6.7 ± 7.7 cm/s⁶ whilst also noting that their volumetric flow studies are generally lower than other reported studies.^{8–10} Similarly Fronek et al. report peak velocities for normal volunteers of the PT at 16 ± 10 cm/s and for the DP at 16.8 ± 5.7 cm/s and less for groups of patients with arterial occlusive disease.¹¹ The reason for these differences is uncertain. A possible reason for the difference between the peak velocities in this study and those in other reported studies is because of the complex physiology of critically ill patients. Furthermore, this study focused on a specific cohort of critically ill patients, namely patients on pVA ECMO. The cardiovascular state of this specific cohort is extremely complex for several reasons. Blood flow to the lower limbs may be dependent upon the interaction between the centrifugal ECMO pump and the patient's haemodynamic profile. As a result, for some patients, there is very little or no arterial pulsatility and flow is generated almost or entirely by the centrifugal pump. For others, with some cardiac function, there may be varying degrees of pulsatility, and lower limb blood flow will be determined by the combination of cardiac function, ECMO pump flow, and how these function together within the vascular tone. In either case, the physiology is altered and may account for some of the difference with other reported studies of patients with normal physiology. Patients on pVA ECMO may also be receiving high doses of vaso-pressors that may lead to constriction of the vessels which might also lead to higher velocities.

The complexity of the reported cohort of patients on VA ECMO is also underlined by the following characteristics. Compared to other patients within this ICU, their mean APACHE 111 score was higher (69.1 vs 58), ICU stay was longer (18.1 vs 1.7 days), ventilation duration was higher (10.5 vs 1.5 days), and as was hospital mortality (53% vs 7.7%). This cohort contained seven (47%) ECPR patients. Of these seven; five died (hospital survival 28.5%). This is approximately in keeping with the ICU's historical survival rates for ECPR which is around 50% for survival of ECMO and about 35% for survival to hospital discharge. The proportion of ECPR patients within the study is partially explained by the circumstances of their cannulation. That is, ECPR usually requires peripheral cannulae to be inserted urgently and, at this centre, a BFC is generally inserted at a later stage (e.g., following an urgent interventional cardiology procedure). Other patients such as those with primary graft failure after heart transplantation or cardiogenic shock after cardiomyotomy are usually cannulated electively in cardiac theatre, and the surgeons are able to select the most appropriate cannulation configuration for the patient (e.g. central, subclavian, or peripheral may be considered). In conclusion, the study cohort therefore included patients at risk of high mortality and morbidity and is a select group. The severity of illness may also result in an augmented inflammatory response, vascular tone changes, and haemostatic perturbations which might explain the differences in the ultrasound parameters measured in this study compared to other reported studies. Unfortunately, we were unable to find any study for comparison that measured Doppler-

derived flow velocities of the lower limbs in patients on pVA ECMO.

5.3. Strengths and limitations

Feasibility in this study was measured via the inclusion rate and the informal feedback of study personnel. This is a limitation as it fails to capture details such as the actual time spent on conducting the Doppler examinations, any disruptions to other clinical responsibilities, and the associated financial costs. A further limitation was that inter-observer correlation was not explored as a part of this study. As a pilot study, there were a limited number of patients to be included and limited resources that could be applied to areas being explored and analysed.

Another limitation of this study is that we only included patients with a BFC in place. According to our results, the presence of a BFC leads to similar PSV in both the cannulated and non-cannulated limbs. None of the patients in our study required treatment for limb ischaemia while some non-study patients within the study period did require intervention. We can only speculate how the absence of a BFC affects ultrasound-derived parameters and whether or not measuring these parameters in patients without BFC might lead to early identification of patients at risk for limb ischaemia. Further studies regarding this issue may therefore be required.

The main strengths of the study relate to aforementioned outcomes of feasibility and relationships between PSV and PP. Other unexpected strengths arose from the adaptability of the pilot design to respond to different circumstances. One of the major impacts on this pilot study was concomitant initiatives implemented simultaneously with the objective of addressing lower limb ischaemia. There was heightened awareness of lower limb ischaemia following two fasciotomies and one incident of ischaemia in the previous year. During the study period, three patients experienced lower limb ischaemia, two received fasciotomy and change of circuit to central configuration, and one received a BFC and was on ECMO for 1 day. Owing to the nature of their circuits and run times, they did not meet the criteria for inclusion in this pilot study. The impacts of these activities on the study included broadened consideration of cannulation configuration and the introduction of an ECMO-specific limb observation chart (See Fig. 5). By comparison, in 2014, 3% of cardiac supported ECMO patients received a central or subclavian type of configuration. In 2016, that proportion had increased to 50%. Patients who received these alternative forms of cannulation were excluded from the study. The introduction of the ECMO-specific limb observation chart might allow risk stratification in that detailed Doppler studies may only be necessary if the limb observations raised concerns. These quality improvement initiatives had a number of impacts: it was more difficult to obtain the required number of participants; the cohort characteristics changed to that originally expected (e.g., high proportion of ECPR patients); and there was an increased focus upon patient safety related to ensuring perfusion of lower limbs.

5.4. Future directions

This pilot study raises a number of issues which require further study. What is the significance of potentially altered flow dynamics on the lower limbs for patients on pVA ECMO? What is the best way of ensuring quality perfusion of the lower limbs, in the context of wide variation in equipment use and clinical practice across ECMO centres (e.g., larger and different types of BFC, selection of smaller arterial return cannulae, monitoring with regional oximetry, and criteria for insertion of BFC)? Should the ECPR group

routinely receive smaller arterial return ECMO cannulae and have specific criteria for early insertion of BFC or change to central/subclavian configuration? When evaluating limb perfusion with Doppler, is it necessary to not only obtain PSV but also velocity time integrals of the examined arteries to quantify flow in low pulsatile states?

6. Conclusion

Whilst it is generally feasible for ICU staff to measure Doppler-derived flow velocities of the lower limbs for patients on pVA ECMO, it remains unclear how clinically useful these measurements are. It appears to be a useful screening tool within ICU for further assessment of peripheral blood flow and pulses when required. What seems more certain is that early identification and referral of lower limb ischaemic issues to experts in the treatment of these complications appears very important for patient outcomes, although this was beyond the scope of the pilot study.

Doppler-derived flow velocities of arteries of the lower limbs of patients on pVA ECMO appear different to non-ECMO patients with normal physiology, which is explainable by the difference of flow that occurs in conjunction with a centrifugal ECMO pump. PSV in the lower limbs of patients on pVA ECMO seems to be more related to PP than to other haemodynamic parameters. This finding appears congruent with the expected physiology of pVA ECMO with BFC.

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