Ultrasonographic assessment of brachial artery reactivity as a predictor of adverse outcome in patients undergoing emergency laparotomy for perforated peritonitis – Prospective observational study

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ABSTRACT

Background and Aims: This study aimed to assess if pre- and postoperative parameters of brachial artery reactivity (BAR), like flow-mediated dilation (FMD) and hyperaemic velocity (HV), could predict in-hospital mortality in perforation peritonitis patients undergoing emergency laparotomy. **Methods:** In this prospective observational study, adult patients with perforation peritonitis undergoing emergency laparotomy were recruited. FMD and HV were measured preoperatively, postoperatively and at 24 and 48 h post-surgery. Adult patients undergoing elective laparotomy served as the control group. The primary outcome was in-hospital mortality. Baseline and BAR parameters were compared between survivors and non-survivors. Risk factors for mortality were identified by univariate analysis. Prognostic performances of BAR parameters were assessed by different models using logistic regression. All statistical analyses were performed on STATA version 13 for Mac OS. **Results:** Seventy-six emergency laparotomy patients were recruited, and 26 died during the hospital stay. FMD and HV were comparable at all time points between survivors and non-survivors, except that HV was higher in survivors at 48 h post-surgery (median [interquartile range] 1.28 [1.16–1.49] vs. 1.16 [0.86–1.35], $P = 0.010$). HV at 48 h predicted mortality (adjusted odds ratio [OR] [95% confidence interval] 21.05 [1.04–422.43], $P = 0.046$), and a model consisting of age, Acute Physiology and Chronic Health Evaluation (APACHE) score and HV at 48 h was the best predictor of mortality (area under the receiver operating characteristic (AUROC) curve 0.82). **Conclusion:** HV, as measured by ultrasonography of the brachial artery at 48 h postoperatively, is a good predictor of mortality in patients undergoing emergency laparotomy for perforation peritonitis.

Key words: APACHE, brachial artery reactivity, endothelial dysfunction, flow-mediated dilation, hyperaemic velocity, mortality, perforation peritonitis, sepsis, surgery, ultrasound

INTRODUCTION

Perforation peritonitis is a common surgical emergency with intra-abdominal sepsis, leading to an overall mortality of 17.86%.[1] Perforation peritonitis and sepsis may lead to multiple organ dysfunction syndrome (MODS) in up to 73% of patients, and mortality increases up to 30%.[2,3] Sepsis is characterised by a dysregulated host response to infection, leading to

organ dysfunction, and endothelial activation and dysfunction play a vital role in the pathogenesis. It is characterised by impaired vasodilation secondary to impaired response to mediators like nitric oxide and dysfunction of endothelial cell lining of the blood vessels of solid organs.[4]

Endothelial dysfunction can be demonstrated noninvasively at the bedside by ultrasound examination of the brachial artery by two parameters: flow-mediated dilation (FMD) and hyperaemic velocity (HV). The utility of FMD has been validated extensively in cardiovascular sciences as a proven risk factor for atherosclerosis.[5] However, limited data on brachial artery reactivity (BAR) in sepsis provides conflicting results. Two studies on BAR in sepsis concluded that HV, not FMD, is a good predictor of mortality.[6,7] In contrast, another study concluded that FMD, not HV, is a good prognostic indicator.[8]

Thus, we planned to evaluate the prognostic utility of BAR in a sepsis model of perforation peritonitis patients undergoing emergency laparotomy. We hypothesised that FMD and/or HV could predict in-hospital mortality in this group of patients. Primary outcome was in-hospital mortality, and secondary outcomes were duration of mechanical ventilation, acute kidney injury (AKI), any requirement of vasopressors and renal replacement therapy (RRT). Patients undergoing elective laparotomy who did not exhibit any features of sepsis were used as a control to evaluate the effect of elective surgery on endothelial dysfunction and the dynamics of BAR in these non-septic patients undergoing elective laparotomy.

METHODS

This prospective observational study was conducted in the emergency operation theatres between January 2019 and December 2020. Institute Ethics Committee approval was obtained for the research (vide approval number ECPG-548 / 14.11.2018 dated 19 November 2018), and the study was registered with the Clinical Trial Registry-India (vide registrtion number CTRI/2018/11/016484, www.ctri.nic.in) before recruitment of the study subjects. The study followed the Declaration of Helsinki, 2013 and was conducted in accordance with the Good Clinical Practice guidelines. Written informed consent was obtained for participation in the study and use of the patient data for research and educational purposes. Adult patients aged 18–65 years with suspected or proven peritonitis

undergoing emergency laparotomy were recruited as study group patients. Consecutive patients undergoing elective laparotomy served as the control group.

Exclusion criteria included patients or their relatives refusing to provide consent, history of intensive care unit (ICU) stay within the last 6 months, pre-existing significant cardiac, renal or hepatic diseases, intraoperative massive blood loss or requiring massive transfusion, and history of coronary artery disease (CAD), cerebrovascular disease (CVA), malignancy, diabetes mellitus, hypertension, metabolic syndrome or peripheral vascular disease (PVD).

Preoperatively, brachial artery diameter and flow were recorded in a supine position in the operation room. The brachial artery was imaged 2 cm above the antecubital fossa with the arm extended. A sphygmomanometer cuff of appropriate size was placed at the widest part of the forearm, 1–2 cm distal to the antecubital fossa. Pre-occlusion two-dimensional (2D) grey-scale images and pulse-wave spectral Doppler recordings were obtained. The cuff was rapidly inflated to find an absent pulse oximeter trace suggestive of absent arterial flow. After 5 min, the cuff was deflated, and pulse-wave spectral Doppler recordings were acquired at 15 s after cuff deflation. Two-dimensional images were obtained 30–90 s after deflation at approximately 15-s intervals. Multiple images were taken at baseline and after occlusion of the brachial artery. Diameters were measured with electronic callipers by using ultrasonically identifiable anatomical landmarks, ensuring a consistent measurement location before and after cuff occlusion in each subject. The diameter of the brachial artery was measured from the media–adventitia interface in the near field to the media–adventitia interface in the far field, both in longitudinal and transverse axes. A series of three diameter measurements for the diameter was averaged at baseline and after deflation. The three maximal post-deflation diameter measurements were used. The peak velocity over a single cardiac cycle was calculated from the pulse-wave spectral Doppler tracing (cm/s). The baseline velocity was the average of three representative Doppler tracings before brachial artery occlusion. HV was the average of the three maximal Doppler tracings 0–15 s after cuff release. The same measurements were taken again postoperatively immediately after surgery and at 24 and 48 h after surgery. The same investigator performed all the sonographic measurements to eliminate interobserver variability,

and Sonosite M-Turbo VR (Fujifilm Inc., Bothell, WA, USA) with a linear probe was used to record all the variables. As the cross section of the vessel was not always circular, and it could be elliptical, two maximal diameters were measured. Subsequently, the area of the vessel was calculated as a cross product of $\pi \times R1 \times R2$ (R=radius). FMD was calculated as the ratio of post-deflation cross-sectional area to pre-inflation cross-sectional area. HV was calculated as the post-deflation peak velocity ratio to pre-inflation peak velocity.[6-8]

General endotracheal anaesthesia without any regional blockade was used in all emergency laparotomy patients, and general endotracheal anaesthesia with epidural catheterisation was used in elective laparotomy patients. However, details of anaesthesia management were left to the discretion of the anaesthesiologist. The patients also underwent arterial blood gas analysis to measure lactate levels before the surgery, immediately postoperatively and 24 h after surgery. In addition to ultrasound-guided parameters, various baseline parameters, including age, sex, Sequential Organ Failure Assessment (SOFA) score, Acute Physiology and Chronic Health Evaluation (APACHE) II score, Mannheim Peritonitis Index (MPI) score, lactate level and outcome parameters including 28-day mortality, mechanical ventilation days, vasopressor days and parenteral nutrition days were assessed.

The sample size was estimated with the easy ROC v. 1.3 web-based tool, which works on the R- platform. We assumed that a change in brachial artery HV would have a predictive validity 0.7 for hospital mortality. A review of our database revealed that around 20%–30% of such patients died during the hospital stay. Based on this result, a sample of 76 patients (considering hospital mortality of 25% in peritonitis patients) achieved 85% power and a probability of 0.05 for rejecting the null hypothesis. Simultaneously, another 75 demographically matched patients without sepsis or any other acute inflammatory conditions, undergoing elective laparotomy were recruited as a control group.

Results are expressed as median with interquartile range. The chi-square test, Fisher's exact test and Mann–Whitney U test were used to compare the baseline and outcome variables between survivors and non-survivors. All the statistical analyses were performed on STATA version 13 for Mac OS (Stata Corp. 2011. Stata Statistical Software: Release 13; Stata Corp LP., College Station,

TX, USA). The primary outcome was a prediction of mortality using BAR. Possible risk factors for in-hospital mortality were identified based on univariate analysis. Using logistic regression, the prognostic performance of BAR was assessed by different models with variables such as age, APACHE II score and BAR variables at other time points. The prognostic performance of BAR in predicting the duration of mechanical ventilation, AKI and requirement of RRT and vasopressor was assessed by various linear regression models with age, APACHE II score and BAR as the independent variables. The goodness of fit was assessed by the Hosmer–Lemeshow test. Receiver operating characateristic (ROC) curves were drawn to calculate the best cut-off values for predicting hospital mortality. Lactate clearance post-surgery and 24 h post-surgery was calculated and compared among survivors and non-survivors. Lactate clearance at 24 h = (pre-op lactate – lactate at 24 h)/pre-op lactate expressed as a percentage. Lactate clearance at the end of surgery = (pre-op lactate – post-op lactate)/pre-op lactate expressed as a percentage. Spearman rank correlation test was used to correlate lactate clearance and BAR.

RESULTS

In this prospective study, 76 patients with perforation peritonitis were recruited with a median (interquartile range [IQR]) age of 30 (23–45) years, and 49 of them were male. All the baseline demographics and outcome data of survivors ($n = 50$) and non-survivors ($n = 26$) are listed in Table 1. Consecutive patients ($n = 75$) undergoing elective laparotomy were recruited as controls. All the patients in the study and control groups completed the follow-up. During the hospital stay, 26 patients (proportion [95% confidence interval {CI}] 34.21 [24.54–45.43]) died. Median (IQR) length of hospital stay was 9.5 (5–28) days.

Non-survivors were similar in age but SOFA score, APACHE II score and MPI score were higher in non-survivors than survivors. The preoperative BAR flow velocity was comparable between the groups. Increased duration of mechanical ventilation, vasopressor requirement and in-hospital mortality were noted among non-survivors compared to survivors [Table 1].

ROC curves were constructed for preoperative, postoperative, 24 h and 48 h postoperative BAR to predict hospital mortality [Table 2, Figure 1]. Best area under ROC (AUROC) was 0.69 and 0.64 for HV and FMD, respectively, at 48 h post-surgery.

Table 1: Baseline, demographics, sonographic and outcome data of survivors and non- of perforation peritonitis undergoing emergency laparotomy				
Parameters	**All patients (*n*=76)**	**Survivors (*n*=50)**	**Non-survivors (*n*=26)**	***P***
Age (years)	30.5 (23–45)	25.5 (21–41)	40 (23–53)	0.066
Gender (M/F) (male/female)	49/27	33/17	16/10	0.700
SOFA	2 (0–4)	0.5 (0–2)	4 (2–6)	<0.001
APACHE II	11 (4–15.5)	6.5 (4–14)	14.5 (11–20)	<0.001
Mannheim peritonitis index (MPI)	12 (8.5–17.5)	9.5 (5–15)	19.5 (11–22)	0.001
Preop FMD	0.98 (0.90–1.04)	0.97 (0.92–1.06)	1.01 (0.90–1.03)	0.308
Postop FMD	0.97 (0.91–1.01)	1.01 (0.92–1.10)	0.96 (0.90–1.03)	0.200
FMD at 24 h	1.05 (0.99–1.09)	1.05 (1.00–1.09)	1.04 (0.98–1.10)	0.870
FMD at 48 h	1.05 (0.99–1.14)	1.07 (1.01–1.14)	1.03 (0.92–1.10)	0.080
HV preoperatively	1.36 (1.04–1.79)	1.36 (1.12–1.68)	1.63 (0.80–2.0)	0.521
HV postoperatively	1.05 (0.84–1.21)	1.05 (0.90–1.26)	0.98 (0.82–1.11)	0.350
HV at 24 h	1.16 (1.05–1.28)	1.17 (1.09–1.28)	1.06 (0.92–1.26)	0.220
HV at 48 h	1.25 (1.11–1.47)	1.28 (1.16–1.49)	1.16 (0.86–1.35)	0.010
Preoperative lactate (mmol/L)	1.8 (0.9–3.3)	1.75 (0.9–2.6)	3.25 (1.4–4.4)	0.009
Mechanical ventilation (days)	1 (0–3)	0 (0–2)	3.5 (1–7)	0.002
Vasopressor (days)	1 (0–3)	0 (0–2)	4 (1–7)	0.001
Total parenteral nutrition duration (days)	0 (0–7)	0 (0–8)	0 (0–5)	0.093
Hospital length of stay (days)	9.5 (5–28)	15.5 (6–29)	6 (2–19)	<0.001

Data are expressed as median (interquartile range) or numbers. APACHE II=Acute Physiologic Assessment and Chronic Health Evaluation II, FMD=flow-mediated dilation, HV=hyperaemic velocity, SOFA=Sequential Organ Failure Assessment score

Table 2: Prognostic performance of brachial artery reactivity in predicting in-hospital mortality of perforation peritonitis patients undergoing emergency laparotomy					
Parameters	**Time**	**AUROC (95% confidence interval)**	**Best cut-off**	**Sensitivity (%)**	**Specificity (%)**
FMD	Preoperative	0.520 (0.38–0.65)	0.920	78	38
	Postoperative	0.590 (0.45–0.72)	0.909	88	26.92
	At 24 h postoperatively	0.503 (0.34–0.66)	0.942	92	21.05
	At 48 h postoperatively	0.643 (0.47–0.81)	0.948	92	37.5
HV	Preoperative	0.458 (0.29–0.61)	0.932	90	30.77
	Postoperative	0.565 (0.43–0.69)	0.906	76	42.31
	At 24 h postoperatively	0.613 (0.44–0.77)	1.070	82	55
	At 48 h postoperatively	0.697 (0.52–0.86)	0.938	100	37.5

FMD=flow-mediated dilation, HV=hyperaemic velocity, AUROC=area under the receiver operating characteristic curve

Possible risk factors for in-hospital mortality were identified based on univariate analysis. The prognostic performance of models using either FMD or HV at different time points (pre-surgery, post-surgery, and 24 and 48 h post-surgery) along with age and APACHE II score was assessed by using logistic regression to predict mortality [Table 3] and organ dysfunction. The baseline APACHE score was significant in all models. In model 8, HV was significant in predicting mortality (95% CI 1.04–422.43, *P* = 0.046).

Similarly, multiple linear regression models were constructed by age, APACHE II score and BAR at different time points (pre-surgery, post-surgery, and 24 and 48 h post-surgery) as independent variables and either days of mechanical ventilation or vasopressor

requirement as a dependent variable. HV at 48 h post-surgery was significant in predicting the duration of vasopressor requirement (coefficient −2.75, 95% CI −5.12 to −0.39, *P* = 0.023). The baseline APACHE II score was significant (*P* < 0.05) in predicting days of mechanical ventilation and vasopressor requirement in all models.

The intraoperative lactate clearance was lower in non-survivors compared to survivors (median [IQR]: −20.7 [−82.1 to 7.77] vs. 0 [−22 to 16.4]; *P* = 0.024). Similarly, postoperative lactate clearance was lower in non-survivors compared to survivors (median [IQR] −2.38 [−56.1 to 22.3] vs. 17.8 [−4.4 to 50]; *P* = 0.021). Spearman rank correlation test was used to find the correlation between BAR and lactate clearance. Lactate clearance at 24 h post-surgery correlated with change
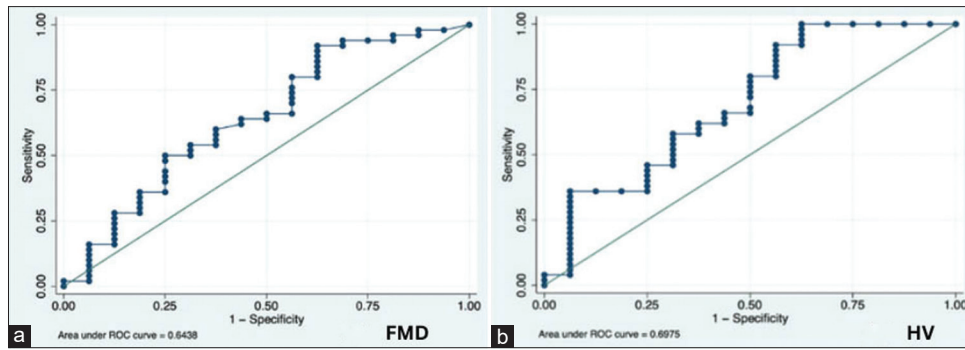
Figure 1: ROC curve for prediction of hospital mortality using (a) FMD at 48 h post-surgery and (b) HV at 48 h post-surgery. FMD = flow-mediated dilation, HV = hyperaemic velocity, ROC = receiver operating characteristic

Table 3: Prognostic performance of logistic regression models to predict in-hospital mortality with change in FMD and HV in perforation peritonitis patients undergoing emergency laparotomy				
Parameters	**Adjusted odds ratio**	**Significance (*P*)**	**95% Confidence interval**	**AUROC for given model**
Model 1				
Age (years)	0.97	0.119	0.93–1.007	0.8
APACHE score	0.86	0.002	0.78–0.94	
Preoperative FMD	2.73	0.46	0.18–40.9	
Model 2				
Age	0.97	0.13	0.93–1.008	0.79
APACHE score	0.86	0.002	0.78–0.94	
Postoperative FMD	3.27	0.39	0.21–50.08	
Model 3				
Age	0.96	0.07	0.92–1.00	0.77
APACHE score	0.88	0.016	0.80–0.97	
FMD at 24 h	0.97	0.99	0.19–48.2	
Model 4				
Age	0.95	0.041	0.91–0.998	0.79
APACHE score	0.89	0.03	0.80–0.99	
FMD at 48 h	7.04	0.12	0.58–84.6	
Model 5				
Age	0.97	0.14	0.93–1.00	0.79
APACHE score	0.85	0.001	0.78–0.94	
Preoperative HV	0.98	0.97	0.45–2.1	
Model 6				
Age	0.97	0.11	0.93–1.00	0.79
APACHE score	0.86	0.002	0.78–0.94	
Postoperative HV	2.04	0.38	0.40–10.30	
Model 7				
Age	0.96	0.057	0.92–1.00	0.80
APACHE score	0.88	0.012	0.80–0.97	
HV at 24 h	2.7	0.36	0.30–24.4	
Model 8				
Age	0.95	0.066	0.91–1.00	0.82
APACHE score	0.90	0.064	0.81–1.00	
HV at 48 h	21.05	0.046	1.04–422.43	

APACHE=Acute Physiology and Chronic Health Evaluation, AUROC=area under the receiver operating characteristic, FMD=flow-mediated dilation, HV=hyperaemic velocity

in area at 24 h post-surgery (rho =0.26 and *P* = 0.029) [Table 4].

Compared to controls, the study group patients were younger in age. Preoperative and postoperative changes in area were significantly lower among study group patients than controls. Preoperative change in velocity was higher, whereas postoperative change in velocity was lower among study group patients. There was a tendency to obliterate difference in 48-h postoperative change in the area. There was no difference in 48-h postoperative change in flow velocity [Table 5].

DISCUSSION

In this prospective observational study, the prognostic value of perioperative BAR designated by FMD and HV at 48 h postoperatively was a good predictor of in-hospital mortality in patients undergoing emergency laparotomy for perforation peritonitis.

Postoperative FMD was not a good predictor, but postoperative HV at 48 h after surgery (i.e., after source control) was a good predictor of mortality with a sensitivity of 100% and specificity of 37%. In a previous prospective observational study, Becker *et al.*[8] concluded that FMD was a good predictor of mortality in sepsis patients, but they did not study HV. They sequentially measured FMD and found that non-survivors had a sequential decline in FMD compared to survivors. However, other previous studies had reported that FMD was not a good predictor.[6,7] It could be due to various methodological issues. The tunica adventitia interface could be more prominent, and diameter measurement may be prone to errors. Another reason could be that the pressure put by the ultrasound probe might alter the measurement of such small changes. Thus, in the current study, one investigator did all the ultrasound measurements, and we reported the change in area in ratio rather than diameter.

The trend in FMD demonstrates a continuous and consistent improvement up to 48 h after surgery in survivors. In contrast, in non-survivors, FMD declines in the postoperative period after a transient improvement at 24 h, possibly due to source control. This observation is similar to the findings from the study by Becker *et al.*[8] In the current study, preoperative FMD was lower in sepsis patients, probably due to endothelial dysfunction. In sepsis patients, especially survivors, postoperative increase in FMD probably denoted some reversibility of endothelial dysfunction. However, baseline HV was higher in the study group patients, probably due to hyperdynamic circulation in sepsis and vasopressor use augmenting cardiac output. In the postoperative period, HV decreased significantly, only to return towards the baseline values in 48 h. Surgical stress, inflammation and ongoing sepsis leading to further endothelial dysfunction could have reduced HV in the postoperative period, which showed a trend towards some reversibility by the 48-h postoperative period. This indicates that endothelial dysfunction and vascular reactivity may return to normal 48 h after source control by surgery.

It is already known that surgical stress elicits inflammatory and endocrine responses and may lead to immune incompetence.[9] Patterns of vascular reactivity in the control patients suggest some endothelial dysfunction after major elective surgeries. This was reflected by the decreasing trend of FMD in postoperative day 2. On the other hand, HV could have increased in the postoperative period due to hyperdynamic circulation, vasopressor use augmenting cardiac output, surgical stress and ongoing resuscitation following major surgery, only to decline afterwards by 48 h, reflecting some endothelial dysfunction. Ekeloef *et al.*[10] similarly observed significant impairment of endothelial function after elective abdominal surgery, denoted by reduced reactive hyperaemia index and biomarkers of nitric oxide availability in the postoperative period. On the other hand, intergroup comparisons revealed that both FMD and HV were significantly different at all time points except HV at 48 h post-surgery. As the study population was completely different, it was challenging to compare these data between the groups meaningfully. However, both FMD and HV were significantly low in the patients with peritonitis in the postoperative period compared to the elective control patients, reflecting impaired vascular reactivity due to endothelial dysfunction in sepsis. Moreover, the timeline of endothelial dysfunction onset from the onset of symptoms in perforation peritonitis

Table 4: Correlation of lactate clearance with brachial artery reactivity in perforation peritonitis patients undergoing emergency laparotomy

Parameters	Correlation coefficient (rho)	Significance (*P*)
Clearance post-surgery		
Preoperative FMD	−0.0014	0.99
Preoperative HV	−0.15	0.17
Clearance 24 h post-surgery		
Postoperative FMD	0.26	0.029
Postoperative HV	0.077	0.52

FMD=flow-mediated dilation, HV=hyperaemic velocity

Table 5: Comparison of brachial artery reactivity parameters at different time points between emergency laparotomy (cases) and elective laparotomy (controls) patients

	All patients (*n*=76) Median (IQR)	Controls (*n*=75) Median (IQR)	*P*
Age	30.5 (23–45)	42 (30–52)	0.001
Preoperative FMD	0.98 (0.90–1.04)	1.13 (1.04–1.21)	<0.001
Preoperative HV	1.36 (1.04–1.79)	1.03 (0.94–1.12)	<0.001
Postoperative FMD	0.97 (0.91–1.01)	1.17 (1.08–1.26)	<0.001
Postoperative HV	1.05 (0.84–1.21)	1.37 (1.17–1.52)	<0.001
FMD at 48 h	1.05 (0.99–1.14)	1.03 (0.91–1.09)	0.020
HV at 48 h	1.25 (1.11–1.47)	1.29 (1.15–1.50)	0.240

FMD=flow-mediated dilation, HV=hyperaemic velocity, IQR=interquartile range

is unknown. This, coupled with the hyperdynamic circulation, ongoing resuscitation and stress of surgery, may explain the initial high HV and delayed decrease of HV in patients with peritonitis.

Wexler *et al.*[6] carried out a case–control study and concluded that FMD was not a reliable predictor of mortality, but HV was a useful bedside method for predicting unfavourable outcomes in sepsis patients. In another case–control study by Omar *et al.*,[7] sepsis patients in an ICU were considered study group patients and cohorts without acute illness were taken as controls. They found that HV was a good predictor of mortality in sepsis patients, while FMD was not. These results are similar to those of the current study.

However, the above studies found that baseline FMD and HV were lower among septic cohorts than non-septic patients. Kazune *et al.*,[11] in a meta-analysis comprising 18 studies, concluded that peak hyperaemic blood flow was lower in patients with sepsis than patients without sepsis. However, only four studies used ultrasound to assess microcirculatory dysfunction. The rest of the studies used peripheral arterial tonometry, laser Doppler flowmetry and plethysmography to assess vascular reactivity in sepsis patients. These findings are in contrast to those of the current study, where only FMD was lower in patients with peritonitis, whereas HV was not. We think the presence of sepsis, ongoing resuscitation, anxiety and stress of impending major surgery led to hyperdynamic circulation in the study group patients, which resulted in elevated HV in the current study. However, sepsis cases in the other studies were either medical or surgical patients who were already admitted to ICU.[6,7]

APACHE II score was significant in all logistic regression models in predicting mortality and organ dysfunction (mechanical ventilation and vasopressor requirement). This is expected as it is a validated score in predicting mortality in sepsis patients.[12] All the models had a fair AUROC in the range of 0.79–0.82 in predicting mortality. HV at 48 h post-surgery was also significant in predicting hospital mortality ($P = 0.047$) and duration of vasopressor requirement ($P = 0.023$). These findings are similar to Vaudo *et al.*,[13] who found that sepsis patients with lower HV at admission had an increased incidence of organ failure at 72 h. They concluded that HV is a good predictor of organ failure in patients with sepsis. However, FMD was not studied as a predictor of organ failure in previous studies. Our research did not predict mortality, vasopressor requirement or mechanical ventilation duration in any of the linear and logistic regression models.

In the current study, the findings of higher lactate levels and lower lactate clearance in non-survivors in the postoperative period are consistent with those of previous studies.[14,15] Lactate clearance values in the current study did not correlate with either FMD or HV. However, we had data on lactate clearance until 24 h post-surgery and could not explore the correlation with HV at 48 h post-surgery.

We studied the importance of measuring BAR in a cohort of sepsis patients where surgical source control could be readily achieved and reversibility of endothelial dysfunction, if any, could be assessed. In previous studies, BAR was assessed in medical or surgical patients in ICU and reversibility of BAR was not assessed in a model where surgical source control could be established.

However, our study has several limitations. First, it was a single-centre study with a relatively small cohort of patients, and we could not validate our findings in an external cohort. Secondly, 11 of the 26 non-survivors died within 48 h of surgery; hence, ultrasonographic data at 48 h were lacking, reducing the impact of statistical significance. However, the baseline FMD and HV of these 11 non-survivors who died within 48 h were comparable to those of survivors and other non-survivors who died after 48 h. Thirdly, we did not use any clinical severity of illness scores, duration of illness or serum levels of biomarkers like procalcitonin/C-reactive protein to risk-stratify patients for inclusion in the study or analysis of results. Another important limitation was that we could not recruit age- and sex-matched controls due to the non-availability of appropriate patients for elective surgery during the coronavirus disease 2019 (COVID-19) pandemic.

CONCLUSION

HV measured by ultrasonography of the brachial artery at 48 h postoperatively is a good predictor of mortality in patients undergoing emergency laparotomy for perforation peritonitis.

Study data availability
De-identified data may be requested with reasonable justification from the authors (email to the corresponding author) and shall be shared upon request.

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Conflicts of interest

There are no conflicts of interest.

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