The association of microalbuminuria and duration of mechanical ventilation in critically ill trauma patients

Kritik travma hastalarında mikroalbüminüri ile mekanik ventilasyon süresinin ilişkisi

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BACKGROUND
Microalbuminuria, which predicts organ failure, probably predicts the necessity of mechanical ventilation as well as its duration. The primary goal of this study was to determine the incidence and presence of a relationship between microalbuminuria and duration of mechanical ventilation in trauma intensive care unit (ICU) patients.

METHODS
Sixty admitted critically ill trauma patients were categorized by duration of mechanical ventilation to group A (≤7 days) or group B (>7 days) in this prospective observational study. We measured serial spot urine micro-albumin-creatinine ratios (ACR) on admission to the ICU (ACR-1), at 24, 72, and 120 hours after admission, and on the days of beginning and discontinuation of mechanical ventilation (ACR-2 and ACR-3, respectively).

RESULTS
Seventy percent of the patients had microalbuminuria and 63.3% had an ACR ≥100 mg g^{-1} at admission. ACR-1 [mean (SE)] in patient groups A and B was 30 (6) and 63 (16) mg g^{-1} (p=0.0002); ACR-2 was 40 (4) and 52 (8) (p=0.007); and ACR-3 was 30 (11) and 44 (11), respectively (p=0.023). For all patients, mean (SE) ACR-2 fell from 37 (4) to 34 (8) mg g^{-1} on the day of discontinuation of mechanical ventilation (p<0.01).

CONCLUSION
The ACR can be used in estimating the risk of prolonged mechanical ventilation, even on the first day of admission of critically ill trauma patients.

Key Words: Critically ill; mechanical ventilation; microalbuminuria; trauma.

AMAÇ
Organ yetersizliğini öngören mikroalbüminüri, muhtemelen mekanik ventilasyon gereksinimi ile birlikte mekanik ventilasyon süresini de öngörmektedir. Bu çalışmanın başlıca amacı, travma yoğun bakım ünitesi hastalarında mikroalbüminüri ile mekanik ventilasyon süresi arasındaki bir ilişkinin varlığını ve insidansını belirlemek olmuştur.

GEREÇ VE YÖNTEM
Bu gözlemsel çalışmada, 60 kritik travma hastası, mekanik ventilasyon süresine göre grup A (≤7 gün) ve grup B (>7 gün) olarak iki gruba ayrıldı. Yoğun bakım ünitesine kabul edilme sırasında (ACR-1), yatırıldıktan sonraki 24., 72. ve 120. saatler ile mekanik ventilasyonun başladığı ve kesildiği günlerde (sırasıyla, ACR-2 ve ACR-3) seri spot idrar mikroalbümin-kreatinin oranları (ACR) ölçüldü.

BULGULAR
Yoğun bakım ünitesine kabul edilme sırasında, hastaların %70'i mikroalbüminüriye ve %63,3'ü de ≥100 mg g^{-1} seviyesinde bir ACR değerine sahip oldu. Sırasıyla A ve B grubu hastalarda ACR-1 [ortalama (SE)] 30 (6) ve 63 (16) mg g^{-1} (p=0,0002); ACR-2, 40 (4) ve 52 (8) (p=0.007); ACR-3 de 30 (11) ve 44 (11) (p=0,023) oldu. Bütün hastalar için ortalama (SE) ACR-2, mekanik ventilasyonun kesildiği gün 37 (4) mg g^{-1} seviyesinden 34 (8) mg g^{-1} seviyesine düştü (p<0,01).

SONUÇ
ACR, kritik travma hastalarının yoğun bakım ünitesine kabul edildiği ilk günde bile uzamış mekanik ventilasyon riskinin tahmin edilmesinde kullanılabilir.

Anahtar Sözcükler: Kritik yaralı; mekanik vantilasyon; mikroalbüminüri; travma.

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Predicting patient outcome is an important component of patient care in critical care units.[1] Patients requiring intensive care frequently have some degree of systemic inflammatory response syndrome (SIRS), which, when severe, places them at risk of multiple organ failure.[2,3] A very early feature of inflammation is increased capillary permeability to plasma proteins, which occurs within a few minutes (min) of injury and usually returns to normal within 6 to 12 hours (h).[4] Capillary leak is amplified by the kidney[5] and can be monitored by measurement of urine albumin. The degree of albuminuria is variable and in most instances may not be clinically detectable using routine urine dipstick testing. Such low rates of albumin excretion (<300 mg day^{-1}) are termed microalbuminuria.[6] The degree of microalbuminuria can be reliably indexed with a spot urine albumin-creatinine ratio (ACR).[6,7]

Recent studies have suggested that measurement of the urine ACR may have some predictive value for organ failure in intensive care unit (ICU) patients.[8-15]

The primary cause of need for mechanical ventilation is acute respiratory failure. Theoretically, every parameter, e.g. microalbuminuria, which predicts organ failure, such as acute respiratory failure, probably predicts requiring mechanical ventilation and the duration of it. Our hypothesis is that increased microalbuminuria on the day of admission to the trauma ICU or when beginning mechanical ventilation is associated with prolonged duration of ventilation. There is no simple inexpensive bedside test that accurately and reliably predicts the duration of mechanical ventilation upon admission to the trauma ICU. The prevalence of microalbuminuria, as a simple, inexpensive, and dynamic marker of critical illness[1] in trauma patients requiring mechanical ventilation, is also unknown. Thus, this study was designed to determine the incidence and presence of a relationship between microalbuminuria and duration of mechanical ventilation in critically ill trauma patients.

MATERIALS AND METHODS

The Institutional Review Board approved the study protocol, which waved formal informed consent in view of the observational nature of the study. All consecutive patients admitted to the trauma ICU were eligible for the study. The study was conducted between September 2005 and December 2006 in a 2000-bed university teaching hospital with a 16-bed ICU. The exclusion criteria were anuria, failure to collect urine samples, being on renal replacement therapy, overtly bloody urine, urinary infection, existing chronic renal disease (serum creatinine level ≥ 2 mg dl^{-1}), or inability to measure urine albumin due to hyperpigmentation of the urine specimen. Patients with a diagnosis of type 1 or type 2 diabetes mellitus, and those receiving nephrotoxic drugs or remaining in the ICU for <48 h were also excluded. Information on the following variables was obtained prospectively for each patient: patient demographic data; admission diagnosis; date of admission; and duration of mechanical ventilation. All patients had a Foley urinary catheter in place. Spot urine samples were obtained on admission to ICU, at 24, 72, 120 hours after admission, and on the days of beginning and discontinuation of mechanical ventilation for quantification of the urine micro-ACR. The Sequential Organ Failure Assessment (SOFA) score, which included serum creatinine and bilirubin, urine output, platelet count, PO_2/FiO_2 ratio, mean arterial pressure, inotrope requirement, and Glasgow Coma Scale score, was calculated on data at the time of admission to the ICU, and on the days of starting and disconnection of mechanical ventilation.[16] Each patient was followed through their ICU stay and the days of beginning and discontinuation of mechanical ventilation, and durations of ventilation were obtained. Urine albumin was measured on an aliquot of urine taken directly from the bladder catheter within 15 min of ICU admission and at the other five time points. Urine albumin was measured by employing enzyme-linked immunosorbent assay (ELISA) method. The analytical range for urine albumin measured by Biomek Automated Laboratory Workstation (Beckman Instruments, Inc., USA) was 1.5 - 400 mg L^{-1}. Results that fell below or above the analytical range were assigned values of 1.5 and 400 mg L^{-1}, respectively. To correct for variations in urine flow rate, results were expressed as the ACR in mg g^{-1}. Clinical proteinuria is defined by ACR ≥300 mg of albumin per gram of creatinine (ACR ≥300 mg g^{-1}). This corresponds to daily albumin excretion of ≥300 mg day^{-1}. ACR values between 30 and 299 mg g^{-1} define microalbuminuria and values <30 mg g^{-1} [17] are considered normal. Duration of ventilation was defined as number of days with mechanical ventilation; no attempt was made to subdivide into hours. The procedure of

weaning from mechanical ventilation began when a patient's condition showed visible improvement or there was a resolution of the underlying cause of respiratory failure. To start the weaning procedure, the following criteria had to be met: spontaneous respiration rate (f) <35 min^{-1}, spontaneous respiratory volume (Vt) >5 ml kg^{-1} body weight, maximum spontaneous inspiratory effort (Pi max) >25 cm H_2O, heart rate <140 min^{-1}, body temperature <38.5°C, hemoglobin >100g L^{-1}, partial arterial oxygen pressure (PaO_2) >60 mmHg, breathing a fraction of inspired oxygen (FiO_2) <0.4 with a positive end expiratory pressure (PEEP) <5 cm H_2O, no need of vasoactive or inotropic support, PaO_2/FiO_2 ratio >200, and f/Vt ratio <100. The procedure of weaning started with 5 min of spontaneous breathing through a T-tube circuit, with the FiO_2 set at the level used during mechanical ventilation. During the 2-h trial, the patient had to meet the following objective criteria: spontaneous respiratory frequency <35 min^{-1}, arterial blood oxygen saturation (SaO_2) >90% at FiO_2 <0.4, heart rate <140 min^{-1} or >20% change from the baseline, systolic blood pressure <200 mmHg or not <80 mmHg, PaO_2 >60 mmHg, pH <7.30, and stable clinical condition. The patients who fulfilled these criteria at the end of the 2-h trial were extubated. The weaning procedure was considered successful if reintubation was not required within 48 h of extubation. If any signs of poor procedure tolerance were observed during the 2-h trial, the patient was switched back to assist/control ventilation mode and considered as a patient with difficult initial weaning. In such patients, the same procedure of weaning was repeated after 24 h, or when the patient's clinical condition permitted it. The patients with weaning difficulties during a 2-h spontaneous breathing trial were followed until ICU discharge or death.

Statistical analysis

Patients were categorized by duration of mechanical ventilation to group A (≤7 days) and group B (>7 days). Differences in ventilation time, ACR, and the SOFA score between the defined groups were assessed using the Mann-Whitney nonparametric test and between time points were analyzed by the Wilcoxon signed rank test. The incidence of microalbuminuria was computed for all patients and groups. Ninety-five percent confidence intervals (95%CIs) were based on the Fisher's exact test. The risk estimate was used as the preferred measure of the strength of association between ACR and duration of mechanical ventilation. The nonparametric Spearman ranked sign procedure was used to assess the significance of associations. Sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV), and positive or negative likelihood ratios (±LR) for SOFA score and ACR in predicting more than 7 days of mechanical ventilation were calculated. Also, receiver operator characteristic (ROC) curves were constructed for each of the predictive variables and the areas under the ROC curves (AUC) were compared. The analyses were facilitated with the use of the MedCalc 9.0.1.1 software packages. Stepwise logistic regression analysis was used to determine which of the above variables was an independent risk factor for more than 7 days duration of mechanical ventilation.

RESULTS

Seventy-four consecutive, critically ill trauma patients were admitted to the ICU during the study period. Of these, 14 patients were excluded: 5 had anuria, 3 had pigmented urine, and 6 patients died before any urine samples could be obtained. A total of 60 critically ill patients were studied. Demographic characteristics and laboratory data of the patients are presented in Table 1. At the time of discontinuation of mechanical ventilation, the SOFA score and ACR significantly decreased compared with the time of beginning ventilatory support ($p<0.01$). As Table 1 shows, there was also significant difference in these variables between patients in groups A and B ($p<0.05$). Admission SOFA scores and ACR were significantly increased in patient group B compared with group A ($p<0.01$). In comparison with group A, duration of mechanical ventilation was significantly increased in group B ($p=0.000$). As Table 2 shows, the incidence of ACR >300 mg g^{-1} in group B patients was significantly higher at the different measurement time points compared with group A ($p<0.05$). On the day of admission to the ICU, the incidence of ACR >100 mg g^{-1} was 63.3% (38/60) and these patients were 8.1 (95%CI, 1.64-39.61) times more likely to have more than 7 days duration of mechanical ventilation than those with a ratio <100 mg g^{-1}. For all patients, more than 7 days duration of mechanical ventilation was significantly associated with SOFA score and ACR at the time of admission to the ICU, beginning of mechanical ventilation, and discontinuation from ventilator (Table 3). The sensitivity, specificity, PPV,

Table 1. Demographics and laboratory data of the study population

	All patients	Group A (n=41)	Group B (n=19)	p
Sex				
Male, n (%)	38 (63.3)	27 (65.9)	11 (57.9)	
Female, n (%)	22 (36.7)	14 (34.1)	8 (42.1)	
Age (year)	42.7±13.5	41.8±12.8	44.5±15.0	
Weight (kg)	62.4±7.1	62.8±6.1	61.4±9.0	
Height (cm)	161.5±8.5	162.3±8.3	159.8±8.8	
Duration of MV (day)	6.2±4.6	3.8±1.9	11.4±4.6	0.000
At admission time				
SOFA	7.3±1.9	6.7±1.8	8.3±1.5	0.002
UMA-1, mg L^{-1} (±SE)	154±23	99±20	260±48	0.001
ACR-1, mg g^{-1} (±SE)	37±10	30±6	63±16	0.006
At start of MV				
SOFA	7.9±1.80*	0.9±1.9	8.8±1.5	0.020
UMA-2, mg L^{-1} (±SE)	186±22*	140.4±22	284±41	0.001
ACR-2, mg g^{-1} (±SE)	37±4*	40±4	52±8	0.007
At discontinuation of MV				
SOFA	4.6±1.9	4.12±2.0	5.63±1.01	0.003
UMA-3, mg L^{-1} (±SE)	65±11	47±11	104.2±30	0.000
ACR-3, mg g^{-1} (±SE)	34±8	30±11	44±11	0.023

Data are presented as mean±SD unless otherwise indicated. MV: Mechanical ventilation; SOFA: Sequential organ failure assessment; ACR-1, -2, -3: Urine microalbumin/urinary creatinine ratio on admission, start of MV, and discontinuation of MV, respectively; *p<0.01 vs at the time of discontinuation of mechanical ventilation.

NPV, ±LRs, and AUC at the best cut-off point for more than 7 days duration of mechanical ventilation are presented in Table 4. Ratio of urine microalbumin to urine creatinine and SOFA score at the time of admission to the ICU (ACR-1, SOFA-1) and on the days of beginning (ACR-2, SOFA-2) and discontinuation (ACR-3, SOFA-3) of mechanical ventilation provided good discrimination (AUC >0.5), as shown in Table 4. The AUCs for ACR and SOFA score at different time points was not significantly different (p>0.05). As Fig. 1 shows, mean ACR level on admission to the ICU, at beginning of mechanical ventilation, at 24, 72, and 120 h after admission to the ICU, and on the day of discontinuation of ventilator was significantly higher in group B patients compared with group A (p<0.05). By performing stepwise binary logistic regression analysis, it was shown that the most powerful predictor of more than 7 days of mechanical ventilation was ACR-1 followed by SOFA-1. An increase of 10 in ACR-1 or of 1 in the SOFA-1 score significantly increased the relative probability of more than 7 days of mechanical ventilation by a factor of 1.005 (95%CI, 1.001-1.009, p=0.007) or 1.690 (95%CI, 1.133-2.520, p=0.01), respectively. The model used implies that these factors can be combined multiplicatively so that they change the relative probability of this variable by 1.70 (1.005 times 1.690).

Table 2. Incidence of microalbuminuria across selected stratifying variables for the study population

Variable	All patients n (%)		Group A n (%)		Group B n (%)		RS (95%CI)	p
	UMA <20	UMA ≥20 mg L^{-1}	UMA <20	UMA ≥20 mg L^{-1}	UMA <20	UMA ≥20 mg L^{-1}		
UMA-1	18 (30.0)	42 (70.0)	17 (41.4)	24 (58.5)	1 (5.3)	18 (94.7)	0.7 (0.4-0.9)	0.02
UMA-24h	14 (23.4)	46 (76.6)	14 (34.1)	27 (65.8)	0 (0)	19 (100)	0.6 (0.5-0.8)	0.02
UMA-72h	11 (18.3)	49 (81.7)	11 (26.8)	30 (73.2)	0 (0)	19 (100)	0.7 (0.6-0.8)	0.01
UMA-120h	21 (35)	39 (65)	21 (51.2)	20 (48.8)	0 (0)	19 (100)	0.5 (0.3-0.7)	0.00
UMA-2	13 (21.6)	47 (78.3)	13 (31.7)	28 (68.3)	0 (0)	19 (100)	0.7 (0.6-0.9)	0.01
UMA-3	19 (31.7)	41 (68.3)	19 (46.3)	22 (57.3)	0 (0)	19 (100)	0.5 (0.4-0.7)	0.00

ACR-1,-2,-3: Urine microalbumin-creatinine ratio on admission, start of mechanical ventilation and discontinuation of mechanical ventilation, respectively.

Table 3. Associations of SOFA score, microalbuminuria, and the ratio of microalbuminuria to urinary creatinine with more than 7 days duration of mechanical ventilation for all patients (Spearman ranked correlations)

	At admission	At start of MV	At discontinuation of MV
SOFA score	rs=0.41, p=0.001	rs=0.30, p=0.018	rs=0.381, p=0.003
UMA, mg L^{-1}	rs=0.43, p=0.001	rs=0.43, p=0.001	rs=0.476, p=0.000
ACR	rs=0.41, p=0.005	rs=0.44, p=0.006	rs=0.307, p=0.021

SOFA: Sequential organ failure assessment; ACR: Urine microalbumin/urinary creatinine ratio; MV: Mechanical ventilation; rs: Ranked Spearman.

Table 4. Prediction of SOFA score and ratio of microalbuminuria to urinary creatinine for more than 7 days duration of mechanical ventilation

Variable	Cut-off Point	Sensitivity (%)	Specificity (%)	PPV (%)	NPV (%)	AUC	+LR	-LR	p
UMA-1, mg L^{-1}	129	66.7	80.5	60.0	84.6	0.776	3.42	0.41	0.0001
UMA-2, mg L^{-1}	62	100	43.9	43.9	100	0.767	1.78	0.01	0.0002
UMA-3, mg L^{-1}	26	100	63.4	54.5	100	0.796*	2.73	0.00	0.0001
ACR-1	20	61.1	68.3	45.8	80.0	0.711	1.92	0.57	0.0062
ACR-2	30	66.7	70.7	50.0	82.9	0.726	2.28	0.47	0.0040
ACR-3	40	33.3	90.2	60.0	75.5	0.674	3.42	0.74	0.0287
SOFA-1	6.0	94.4	51.5	45.9	95.5	0.758	1.94	0.11	0.0004
SOFA-2	7.0	77.8	48.8	40.0	83.3	0.673	1.52	0.46	0.0301
SOFA-3	4.0	88.9	58.5	48.5	92.3	0.738	2.14	0.19	0.0015

ACR: Urine microalbumin/urinary creatinine ratio; SOFA: Sequential organ failure assessment; MV: Mechanical ventilation; PPV: Positive predictive value; NPV: Negative predictive value; AUC: Area under curve; LR: Likelihood ratio; 1; on admission; 2; on start of MV; 3; on discontinuation of MV. * p<0.05 vs ACR-3.

DISCUSSION

This study of critically ill trauma patients admitted to the ICU of a university teaching hospital suggests a high incidence (70%) of microalbuminuria on the first day of admission. The highest incidence was found on the day of connecting the patients to the mechanical ventilation (78.3%). Approximately 63% of the patients had ACR level between 30 and 300 mg g^{-1}. Our study showed that on the day of admission to the ICU, patients with a ACR >100 mg g^{-1} were approximately 8 times more likely to have more than 7 days duration of mechanical ventilation than those with a ratio <100 mg g^{-1}.

Population data from the Third National Health and Nutrition Examination Survey suggest microalbuminuria occurs at a baseline rate of 3.3% in healthy adults without diabetes, hypertension, cardiovascular disease, or increased serum creatinine level and at a rate of 29% in nonhospitalized adults with diabetes mellitus.[18] It is not surprising that ACRs are several-fold higher in critically ill patients; increased rates have previously been reported in patients with acute stroke, acute pancreatitis, myocardial infarction, and other causes of acute medical illness.[12,19-24] Many of the causes of critical illness are associated with intense inflammatory responses. The cascade of events, triggered by the release of interleukins and other inflammatory mediators, results in widespread endothelial dysfunction.[23,24] Dramatic alterations in vascular, including glomerular, permeability occur. More albumins are filtered than usual. The renal concentrating mechanisms further amplify the albumin concentration, ultimately overwhelming the tubular resorptive capacity, leading to increased albuminuria. The degree of albuminuria is dependent, in part,

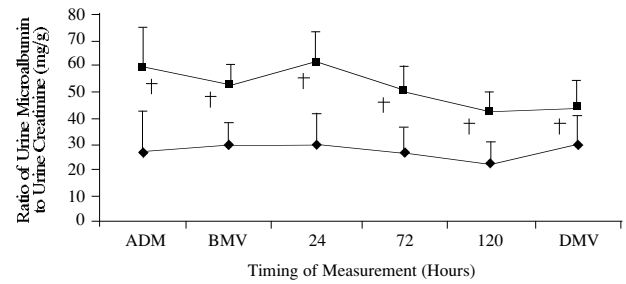

Fig. 1. Change in ratio of urine microalbumin to urine creatinine on trauma intensive care unit (ICU) admission (ADM), on beginning of mechanical ventilation (BMV), 24, 72, 120 hours after admission to the ICU, and on the day of discontinuation of mechanical ventilation (DMV) for patients with less or more than seven days of MV (VD < 7 or VD > 7). Data are presented as mean ± SE. * P < 0.01; † P < 0.05. ■ = Patients with VD > 7; ◆ = Patients with VD ≤ 7.

on the intensity of the inflammatory responses and on baseline integrity of the glomerular capillary wall. Therefore, microalbuminuria is expected and its magnitude should vary with disease severity. Although significant renal protein loss can worsen critical illness and delay recovery, for the most part, the observed increased albuminuria is only a marker of the disease severity and not the cause of it. The ACR is a validated, simple, inexpensive measure of the albumin excretion rate.[7,25-27] It adjusts for variable urine concentrations among patients and obviates the need for a 24-h or timed urine collection. The choice of ACR ≥100 mg g^{-1}, approximately three times the upper limit of normal, for defining microalbuminuria, as a threshold for predicting outcomes was empirical, although a priori specified. A three-fold excess, it was surmised, would separate the moderate-to-severe albuminuria and improve its predictive utility in a population with expected high prevalence of albuminuria. It is expected that replication of our findings in other centers and the aggregation of these results will yield a more definitive threshold value that can be applied in clinical practice across centers.

Early and accurate identification of patients with the highest risk of prolonged duration of mechanical ventilation allows for aggressive therapeutic interventions, optimum resource allocation of nursing and other resources, and appropriate family and/or patient counseling. In our study, ACR and SOFA score on the initial days of admission to the trauma ICU were significantly higher in group B patients compared with group A. They were also potent independent predictors for more than 7 days duration of mechanical ventilation. It seems that the more severe the organ injury, as implicated from the SOFA score calculation, the higher the ACR level and the greater the duration of mechanical ventilation to be expected. Most of the studies of microalbuminuria are consistent in demonstrating its association with increased morbidity and long-term mortality.[20,24,28] More recently, Abid and co-workers[14] demonstrated an association between increasing microalbuminuria over the first 48 h and in-hospital mortality, development of acute respiratory failure, and multiple organ failure. Increasing albuminuria (comparing trend over the first 48 h) had a sensitivity of 60% and a specificity of 68% in predicting mortality. As implicated from Abid et al.'s study,[14] respiratory failure, the primary cause necessitating mechanical ventilation, was more common in patients with increased microalbuminuria during the days of hospital admission. It is thus logical that the duration of mechanical ventilation in these patients becomes more prolonged and persistent. In animal studies of acute respiratory distress syndrome (ARDS) and multiple organ failure initiated with complement activation and hypoxia, not only are the characteristic changes of hydrostatic pulmonary edema and inflammatory infiltration produced in lungs, but similar effects are seen in the vascular beds of other organs with signs of microvascular failure. Assessment of alterations in endothelial permeability, such as the presence of microalbuminuria, may thus be a useful, early, and simple indicator of patients at risk for development of acute respiratory failure and multiple organ failure.[29] Our study provided confirmatory evidence that albuminuria determined on the first day of ICU admission and at the beginning and discontinuation of mechanical ventilation provides a threshold value for maximizing the predictive characteristics of ACR. Pallister and colleagues[8] evaluated the predictive value of microalbuminuria to predict ARDS after trauma. The reference standard used was the Injury Severity Score (ISS). In their sample of 47 trauma patients, microalbuminuria at 8 h after admission was able to predict the onset of ARDS. Degree of microalbuminuria was quantified using the albumin excretion rate. At a threshold albumin excretion rate of >130 mg min^{-1}, the PPV was 85% and NPV was 95%. Pallister and co-workers[30] also assessed the predictive value of microalbuminuria to predict ARDS in a second study. This was conducted in two centers. A point of care device was used to measure albumin excretion rate at 2-h intervals for 24 h. The albumin excretion rate was significantly greater in those patients who developed ARDS. In the current study, a statistically significant association between increasing albuminuria over a 5-day period and more than 7 days duration of mechanical ventilation was also documented.

We found very high incidence of microalbuminuria in critically ill trauma patients. Albumin excretion of 30-300 mg g^{-1} or more is an independent predictor of more than 7 days duration of mechanical ventilation. It is comparable in its prognostic characteristics to the widely used SOFA score, and both the ACR and SOFA score can be used together in estimating the risk of prolonged mechanical ventilation, even on the first day of admission of critically ill

patients. It is also concluded that maintaining the level of ACR in normal range could shorten the duration of mechanical ventilation. Future studies need to be conducted to determine the optimal timing as well as the threshold reference value for the urine ACR in a heterogeneous adult ICU trauma population. Thereafter, large-scale multiple-center, prospective epidemiologic studies must be conducted to confirm and validate the findings of these preliminary studies.

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