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URINE OUTPUT CALCULATED USING ACTUAL BODY WEIGHT MAY RESULT IN OVERESTIMATION OF ACUTE KIDNEY INJURY FOR OBESE PATIENTS

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ABSTRACT—**Goal:** The derived hourly urine output (UO) indexed by body weight is one of the major criteria for the diagnosis of acute kidney injury (AKI). However, it is unclear whether actual body weight (ABW) or ideal body weight (IBW) should be used. This study aims to explore whether UO calculation based on ABW might lead to overestimation of AKI. **Method:** AKI patients identified in the Medical Information Mart for Intensive Care III database by different components of the Kidney Disease Improving Global Outcomes guidelines and different definitions of body weight were retrospectively studied. Hospital and 90-day mortality were compared to decide whether different patient groups had the same outcome. **Results:** In the cohort of 14,725 patients, AKI was identified in 4,298 (29.19%) and 3,060 (20.78%) patients respectively when ABW or IBW was used ($P < 0.01$). Multivariate logistic regression revealed that AKI patients identified by UO calculated from ABW had similar hospital and 90-day mortality to that of patients with no evidence of AKI. Whereas AKI patients identified by serum creatinine changes, or those identified by both ABW and IBW, had twice higher the risks of hospital death and about 1.5 times higher the risks of 90-day death compared with thoese with no evidence of AKI. Results were confirmed in two separate sensitivity analyses where patients whose admission creatinine levels were within the normal reference ranges and patients identified as sepsis were studied. **Conclusions:** Calculating hourly body weight normalized UO using ABW may lead to underestimation of UO and overestimation of AKI.

KEYWORDS—AKI, body weight, mortality

INTRODUCTION

Acute kidney injury (AKI) has been reported to occur in over 50% of the critically ill and associated with increased mortality (1). Although several definitions and guidelines have been proposed over the past few decades, the Kidney Disease Improving Global Outcomes (KDIGO) criteria have been widely accepted by researchers and applied in clinical practice around the world (2). KDIGO defines AKI by both alternations in serum creatinine (SCr) levels and body weight normalized hourly urine output (UO).

However, the KDIGO guideline failed to specify whether actual body weight (ABW) or ideal body weight (IBW) should be used when calculating body weight normalized UO and acknowledged the need for more research on urinary output criteria on AKI staging (2, 3). Therefore, the questions of which body weight definition would be more suitable and should be used for AKI diagnosis and further, whether there would be any difference between AKI patients identified by the two different body weights arose (4–6). For obese and underweight patients, ABW and IBW could differ significantly, leading to differences between UO calculated from them and thus might result in discrepancy regarding diagnosis and staging of AKI. Specifically, ABW is usually bigger than IBW for an obese patient. When calculating hourly UO, using ABW rather than IBW tends to yield smaller values, more likely to be lower than the thresholds defined by KDIGO guidelines. As a result, an obese patient is more likely to be diagnosed as AKI when using ABW instead of IBW to calculate body weight normalized hourly UO.

In this study, we utilized data from the Medical Information Mart for Intensive Care III (MIMIC-III) database and explored differences between patients diagnosed by different components of the KDIGO guidelines and different definitions of body weights. We hypothesized that using ABW might lead to underestimation of patients' hourly UO and subsequently overestimation of AKI.

PATIENTS AND METHODS

Study population

We used data from the MIMIC-III database v1.4, a collaboration between the Beth Israel Deaconess Medical Center (BIDMC) and the Laboratory for Computational Physiology at the Massachusetts Institute of Technology (MIT) (7). It is a single-center database containing 38,597 distinct patients and 49,785 hospital admissions between 2001 and 2012 at BIDMC, a 700-bed teaching hospital of Harvard Medical School in Boston, Massachusetts with 77 adult intensive care unit (ICU) beds. Data in the database includes patients' vital signs, laboratory tests, observations, and notes charted by care providers, fluid balance, procedure codes, diagnostic codes, imaging reports, length of hospital stay, and survivals. All the patients in the database were deidentified and analysis of the data is unrestricted once a data use agreement is accepted. The MIMIC-III database received ethical approval from the institutional review boards at BIDMC and MIT and the requirement to obtain any informed consent was waived because the database does not contain any protected health information available to the researchers.

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To ensure independence of between hospital admissions, we only included the first ICU stay of each patient. ICU stay records shorter than 24 h or without adequate records of UO and SCr (less than two available measurements of both) were also excluded. An age of older than 89 years was shifted and thus not available in the database, so we only included patients with an age between 18 and 89 years. We then dropped all patients whose body weight or height was not documented within first day of their ICU stay. Patients diagnosed with end-stage renal disease (ESRD) as documented by the International Classification of Diseases 9th Revision (ICD-9) codes were also excluded.

AKI definition and grouping of patients

AKI was diagnosed according to KDIGO guidelines: increase in SCr by $\geq$0.3 mg/dL (26.5 μmol/L) within 48 h or increase in SCr $\geq$1.5 times of baseline which is known or presumed to have occurred within the prior 7 days, or urine volume $\leq$0.5 mL/kg/h for 6 h (2). Admission SCr, defined as the first available value documented 24 h prior to or 6 h after ICU admission, was used as baseline as seen in the literature (8). ABW and height were defined as the first available values documented within 24 h after admission to ICU. IBW was then calculated as previously reported (9):

For males: IBW (kg) = 50 kg + 0.91 × [Height (cm) − 152.4]

For females: IBW (kg) = 45.5 kg + 0.91 × [Height (cm) − 152.4]

For patients whose ABW $\geq$ 1.3 times of their IBW, IBW was further adjusted as (10):

Adjusted IBW = IBW + 0.4 × (ABW − IBW)

To calculate UO normalized by body weight, we used ABW and IBW separately. Diagnosis of AKI was made when SCr or UO calculated by either ABW or IBW met the aforementioned thresholds using established code (11). Patients who received renal replacement treatment without documented ESRD were also diagnosed AKI. Body mass index (BMI) was calculated using ABW and height and then categorized: underweight (BMI < 18.5), normal (18.5 $\leq$ BMI < 25), overweight (25 $\leq$ BMI < 30), and obese (BMI $\geq$ 30).

To further illustrate differences among subsets of the patients diagnosed by the two components of KDIGO definition, we divided the patients into the following groups: those diagnosed by ABW- but not IBW-normalized UO or by SCr (referred to as the ABW group), those by IBW- but not ABW-normalized UO or by SCr (the IBW group), those by SCr alone but not by ABW-/IBW-normalized UO (the SCr group), those by both ABW- and IBW-normalized UO but not by SCr (the BW group) and those who were not diagnosed with AKI by either ABW-/IBW-normalized UO or SCr (the non-AKI group).

Covariables

Demographic features such as age, gender and BMI, ethnicity (White, Black, Asian, Hispanic, and others) were included. Patients' comorbidities, including congestive heart failure, hypertension, diabetes, cancer, obesity, and weight loss as indicated by ICD-9 codes, were extracted and coded as binary variables. Other charted data and laboratory tests within the first day of ICU stay were included as continuous variables: The Sequential Organ Failure Assessment (SOFA) score, white blood cell count and hematocrit, serum sodium, potassium, chloride, bicarbonate, anion gap, and glucose and blood urea nitrogen. Admission creatinine level, the highest, lowest and range of creatinine values within the first week of ICU stay were also included. Whether or not vasopressors, mechanic ventilation, or renal replacement treatment were required within the first week of ICU stay were encoded as 0 or 1 and included as binary variables.

Outcome measures

The outcome indicators were hospital mortality and 90-day mortality. Deaths were recorded in the database and originally identified from hospital records or the Social Security Death Index.

Sensitivity analysis

To decide the robustness of our results, two sensitivity analyses were carried out. Patients' serum creatinine might have been elevated to an abnormal level and AKI might have occurred before they admitted into ICU, so using the admission creatinine level 24 h prior to or 6 h after ICU admission as baseline could be questionable. To address this issue, in our first sensitivity analysis, we only included patients whose admission creatinine levels were within the normal reference ranges (below 1.3 mg/dL for male and 1.1 mg/dL for female respectively). In the second sensitivity analysis, sepsis patients were identified based on Angus's proposals (12) to examine whether the results were any different for this specific subset of patients.

Study design

We hypothesized that higher hospital- and 90-day mortality would be observed in AKI patients compared with non-AKI patients. Given that ABW of obese patients would be larger than their IBW, calculating body weight normalized urine output using ABW instead of IBW would always produce smaller values, more likely to satisfy the AKI threshold defined. To test our hypothesis, patients identified as AKI by different components of the KDIGO guidelines were extracted and divided into groups. Logistic regression models were constructed to decide whether AKI defined by SCr or urine output calculated from different definitions of body weights were associated with higher mortality risks compared with non-AKI patients. If obese patients were misclassified as AKI patients, it was assumed that their short- and long-term mortality would be similar to that of patients with no evidence of AKI, and lower that of true positive AKI patients.

Statistical analysis

Continuous variables were reported as medians with interquartile ranges (IQR, 25th–75th percentiles) and categorical variables as counts with percentages. Missing data were imputed using the multiple imputation by chained equations with 5 imputation and 100 iterations. Mann–Whitney *U* test and Kruskal–Wallis test were used to compare continuous data, and Fisher exact test or Pearson chi-squared test to compare categorical data when appropriate. Association between variables was assessed by the Spearman correlation and existence of multicollinearity in models was detected with variance inflation factors (VIFs), correlation coefficients below 0.30 and VIFs below 1.5 were deemed acceptable. Discrepancies between diagnosis of AKI based on different components of KDIGO guidelines were assessed by the McNemar chi-squared test and agreement by Cohen's weighted kappa values and agreement percentages. Logistic regression analyses were used to explore and identify independent variables associated with hospital and 90-day mortality. After removing variables that were highly correlated, the left ones were fed into a full model. Then a stepwise removal of nonsignificant variables from the model until all variables left were significant was carried out based on the Akaike information criterion. The Bonferroni correction was applied in pairwise comparisons among multiple groups. All statistical analyses were performed using R software 3.6.3 (13).

RESULTS

Baseline characteristics

The MIMIC-III database contains 61,532 unique ICU stay records. Of them 10,925 (17.75%) were removed because patients' age was younger than 18 or older than 89. To ensure independence between hospital stay records, 14,090 (22.90%) records identified as non-first ICU stays were excluded. Five thousand five hundred eighty-six (9.08%) patients who stayed less than 24 h in ICU were also excluded. Diagnosing AKI requires admission serum creatinine, UO and patients' height and weight, so 14,233 (23.13%) patients lacking this necessary information were discarded. We also excluded 1,973 (3.21%) patients with previous diagnosis of ESRD. Thus, a total of 14,725 patients were eventually included in the current study (Fig. 1). In all variables included in this study, there was less than 1% missing data, which was imputed as described in *Materials and Methods* section.

Characteristics and outcomes of the cohort are summarized in Table 1. Eight thousand seven hundred ninety-two (59.71%) of the patients were male. Median age was 65 years (IQR 54–76) and median ABW and IBW were 80 kg (IQR 68–94) and 70 kg (IQR 61–78) respectively. Ten thousand six hundred one (72.00%) patients were White and 11,189 (75.99%) came to ICU as emergency admission. Median of first-day SOFA score was 2 (IQR 4–6). Seven thousand three hundred sixty-two (50.00%) patients received vasopressors treatment during their ICU stay. Mechanical ventilation was used in 9,432 (64.05%) of the patients. Hospital mortality was 8.82% among the cohort, while 90-day mortality was 14.50%.

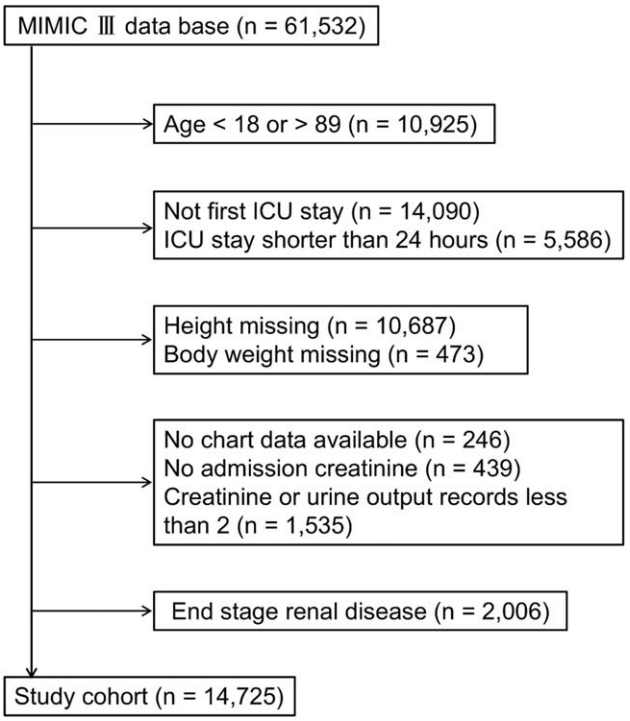

Fig. 1. **Flow chart of patient selection process.** The MIMIC-III v1.4 includes a total of 61532 ICU admission records. A final cohort of 14,725 were identified eligible and included in this study. ICU indicates intensive care unit; MIMIC, Medical Information Mart for Intensive Care.

AKI diagnosis and staging

AKI was found in 4,298 (29.19%) and 3,060 (20.78%) patients when ABW or IBW was used to calculate hourly UO, respectively. Apart from that, AKI occurred in 3,551 (24.12%) patients according to their SCr change. Taken together, a total of 6,033 (40.97%) patients were diagnosed with AKI when SCr and ABW-normalized urine volume were considered and 5,152 (34.99%) patients when considering SCr and IBW-normalized urine volume. Using SCr-based diagnosis as reference, AKI diagnosis based on ABW-normalized urine output yielded a sensitivity of 0.51 (95% CI: 0.49–0.53) and a specificity of 0.78 (CI: 0.77–0.79), while IBW-based diagnosis yielded a sensitivity of 0.41 (95% CI: 0.39–0.43) and a specificity of 0.86 (CI: 0.85–0.86). Significantly more patients were identified as AKI by ABW than by IBW, which were confirmed by McNemar chi-squared tests ($P < 0.001$). In addition, AKI stages also differed between these patients ($P < 0.001$) with Cohen's weighted kappa of 0.87 (95% CI, 0.86–0.88) and agreement percentage of 90.40%. Specifically, 859 patients were identified as AKI by ABW- but not IBW-normalized UO, while 377 patients classified as stage 2 AKI by ABW-normalized UO were classified as stage 1 AKI by IBW-normalized UO (Table 2). When body weights of these 1,236 patients were plotted out and analyzed, it was found ABW (median 93 kg, IQR 82–106) of these patients were significantly larger than their IBW (median 75 kg, IQR 66–84) ($P < 0.001$, Fig. 2A). As a result, urine output of the first 24 h during their ICU stay normalized by ABW was significantly smaller compared with that by IBW ($P < 0.001$, Fig. 2B).

Table 1. **Patient characteristics and outcomes**

Characteristics	Total (n = 14,725)
Age	65 (54–76)
Gender (male)	8,792 (59.7)
Ethnicity	
Asian	319 (2.2)
Black	910 (6.2)
Hispanic	431 (2.9)
White	10,601 (72.0)
Other	2,464 (16.7)
Admission type	
Elective	3,083 (20.9)
Emergency	11,189 (76.0)
Urgent	453 (3.1)
Height (cm)	170 (163–173)
ABW (kg)	80 (68–94)
IBW (kg)	70 (61–78)
BMI (kg/m^2)	27.5 (24.1–31.8)
Hospital death	1,300 (8.8)
90 day death	2,135 (14.5)
LOS in ICU	2.7 (1.6–5.0)
Creatinine (mg/dL)	
Admission	0.90 (0.70–1.20)
7-day minimum	0.70 (0.60–0.90)
7-day maximum	1.10 (0.80–1.50)
7-day change	0.30 (0.20–0.60)
Comorbidities	
CHF	1,707 (11.6)
Hypertension	133 (0.9)
Diabetes	3,759 (25.5)
Cancer	1,133 (7.7)
Obesity	900 (6.1)
Weightloss	516 (3.5)
SOFA score	4 (2–6)
Vasopressor use	7,362 (50.0)
Ventilation	9,432 (64.1)
RRT	485 (3.3)
First lab tests	
WBC (1e9/L)	11.2 (8.1–15.2)
Hematocrit (%)	35.7 (31.1–40.0)
Sodium (mEq/L)	138 (136–140)
Potassium (mEq/L)	4.1 (3.7–4.4)
Chloride (mEq/L)	104 (101–108)
Bicarbonate (mEq/L)	24 (21–26)
Anion gap (mEq/L)	14 (11–16)
BUN (mg/dL)	17 (13–25)
Glucose (mg/dL)	125 (105–162)

Continuous variables were presented as medians with interquartile ranges (25th–75th percentiles) and categorical variables as counts with percentages.
ABW indicates actual body weight; BMI, body mass index; BUN, blood urea nitrogen; CHF, chronic heart failure; IBW, ideal body weight; LOS, length of stay; RRT, renal replacement therapy; SOFA, sequential organ failure assessment.

Among those diagnosed with AKI according to either SCr or hourly UO, 1,443 patients were diagnosed by SCr, ABW-, and IBW-normalized UO at the same time, while 1,535 were diagnosed by both ABW-/IBW-normalized UO but not SCr (the *BW group*), 947 by ABW only but not IBW or SCr (the *ABW group*), 66 by IBW only but not ABW or SCr (the *IBW group*), and 1,719 by SCr but not ABW-/IBW-normalized UO (the *SCr group*). Eight thousand six hundred twenty-six (58.58%) patients with no evidence of AKI were defined as the *non-AKI group* (Fig. 3).

Table 2. **AKI diagnoses and staging**

		AKI stages (IBW)			
		0	1	2	3
AKI stages (ABW)	0	8,626	59	7	0
	1	859	3,032	15	0
	2	88	377	910	0
	3	0	0	8	744

ABW indicates actual body weight; AKI, acute kidney injury; IBW, ideal body weight.

Association between AKI defined by different body weights and mortality

As the incidence of AKI in ABW group was higher than that in other groups, we assumed that using ABW instead of IBW tended to underestimate patients' hourly UO, resulting in these patients more likely to be identified as AKI. Thus, details about the AKI defined by different body weight and mortality were summarized in Table 3.

The hospital and 90-day mortality of the ABW group were significantly lower than that of the BW group and the SCr group ($P < 0.001$). Interestingly, no differences were found in hospital and 90-day mortality between ABW group and non-AKI group. This indicated that a subset of patients was overestimated as AKI due to lower UO calculated from heavier body weights, while their hospital and 90-day risks of death were in fact not different from non-AKI patients. We also found significantly higher hospital and 90-day mortality in BW and SCr groups compared with either ABW or non-AKI group (all $P < 0.001$), while no differences were found between the two groups, suggesting that the subset of patients identified by SCr or both ABW and IBW were at greater risks of hospital and 90-day death than non-AKI patients or those identified by ABW alone. To our surprise, SOFA scores of patients identified as AKI by ABW were significantly higher compared with non-AKI patients ($P < 0.001$) but not significantly different from patients diagnosed with AKI by both ABW and IBW ($P = 0.19$).

Taken together, using ABW to calculate UO tended to overestimate AKI incidence in patients with heavier body weight. While in fact risks of hospital or 90-day death of these patients were significantly lower than those diagnosed by SCr or UO calculated from both ABW and IBW and not significantly different from non-AKI critical ill patients.

Logistic regression

Univariable and multivariable logistic regression models were then constructed to decide independent risks factors. Using non-AKI group as reference, our first model containing only the group variable (hereafter referred to as the *raw model*) revealed that BW group and SCr group were significantly related to higher hospital and 90-day mortality while IBW group was found to be associated with 90-day but not hospital mortality (Table 4). We also noticed that ABW group was associated with neither hospital mortality nor 90-day mortality, while both BW and SCr groups had odds ratios of over two in regards to hospital mortality compared with the non-AKI group. In the second model, age, gender, and BMI were included besides the group variable (the *adjusted model*). In this model, similar to the *raw model*, while both BW group and SCr group were associated with significantly higher hospital and 90-day mortality, ABW and IBW groups were not (Table 4, Supplemental Digital Content 1 Table S1 and Table S2, http://links.lww.com/SHK/B324). The highest, the lowest, admission, change of creatinine, and the first BUN levels within the first 7 days in ICU were all found to be highly correlated, so did the time it took to reach the highest and lowest creatinine, blood

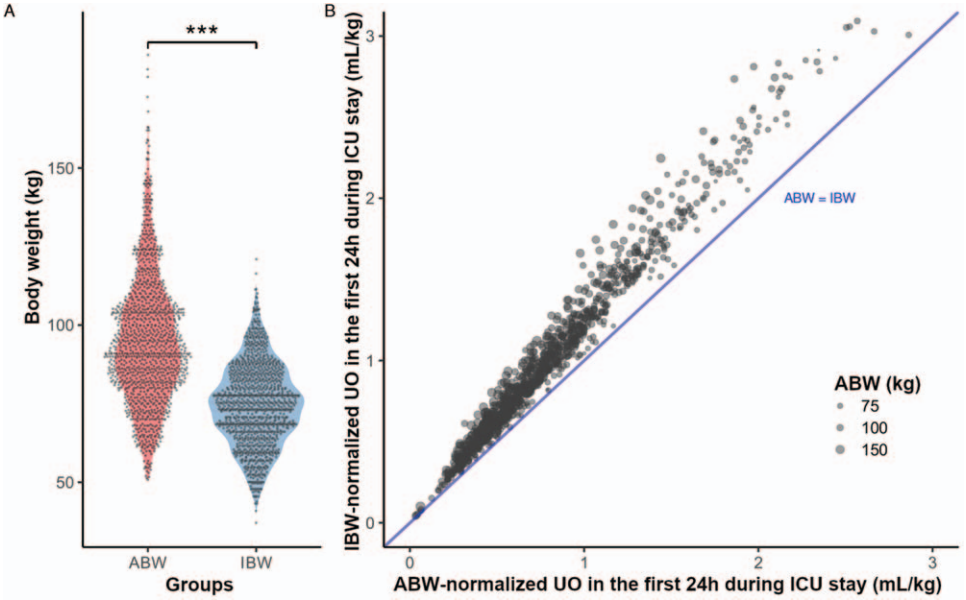

Fig. 2. **Body weights and first 24 h urine output normalized by body weights.** A, ABW and IBW of 1,236 patients identified to different AKI stages by urine output. Significant difference was found between ABW (median 93 kg, IQR 82–106) and IBW (median 75 kg, IQR 66–84). B, Body weight normalized UO of the first 24 h during ICU stay of 1,236 patients identified to different AKI stages by urine output. Blue line indicated UO normalized by ABW and IBW are equal. The scatter plot revealed that UO normalized by ABW was smaller than that normalized by IBW in these patients. ABW indicates actual body weight; AKI, acute kidney injury; IBW, ideal body weight; ICU, intensive care unit; UO, urine output; *** indicates $P < 0.001$.

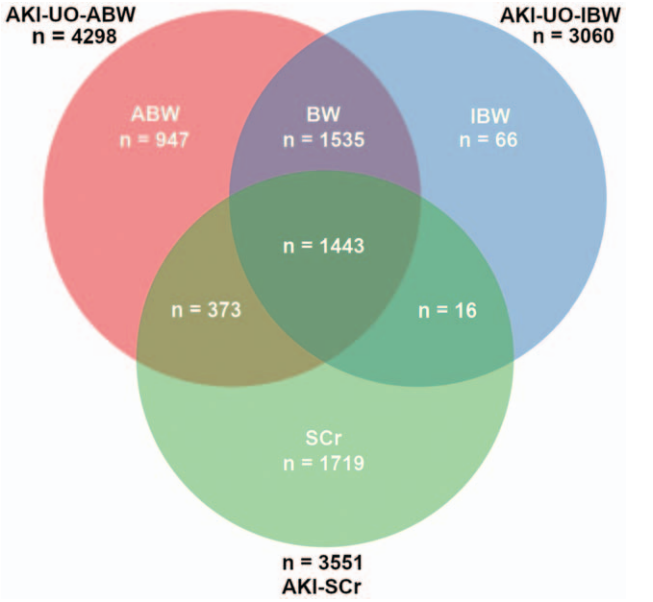

Fig. 3. **AKI patients identified by different components of the KDIGO guidelines and grouping of patient.** Nine hundred forty-seven patients were diagnosed as AKI by ABW only but not IBW or SCr (AKI-UO-ABW, the *ABW group*), 66 by IBW only but not ABW or SCr (AKI-UO-BW, the *IBW group*) and 1,719 by SCr but not ABW-/IBW-normalized UO (AKI-SCr, the *SCr group*). ABW indicates actual body weight; AKI, acute kidney injury; BW, body weight; IBW, ideal body weight; KDIGO, Kidney Disease Improving Global Outcomes; SCr, serum creatinine; UO, urine output.

sodium and chloride levels, blood chloride and bicarbonate levels, as well as bicarbonate and anion gap levels. Thus, variables including the highest, the first, the lowest and the change of creatinine levels, the time it took to reach the lowest creatinine, blood BUN, chloride, and anion gap levels were dropped and then a model including all the remaining variables was constructed (the *full model*). Though odds ratios shrank slightly after being adjusted by more variables, still we found that BW group and SCr group were linked to significantly higher mortalities compared with non-AKI group while neither ABW group nor IBW group was (Table 4, Supplemental Digital Content 1 Table S1 and Table S2, http://links.lww.com/SHK/B324). Finally, a stepwise model excluding variables that were not significant in the *full model* was built (the *reduced model*). The *reduced model* showed similar results to the above models, where only BW group and SCr group but not ABW group and IBW group were found to be linked to higher risks of death compared with non-AKI group (Table 4, Supplemental Digital Content 1 Table S1 and Table S2, http://links.lww.com/SHK/B324).

Sensitivity analysis

When limiting patients to those with admission creatinine within the normal range, 4,300 patients with abnormal creatinine levels at ICU admission (above 1.3 mg/dL for male or 1.1 mg/dL for female) were dropped and a cohort containing the left 10,425 patients was analyzed. Four logistic regression models were built following same procedures as mentioned earlier. The results still demonstrated that both BW and SCr groups were linked to higher hospital and 90-day mortality, while ABW and IBW groups were not (Supplemental Digital Content 2 Table S3, http://links.lww.com/SHK/B325).

When the patient cohort was limited to those with ICD-9 codes indicating sepsis during their ICU stay as proposed by Angus et al. (12), a total of 3,365 cases were identified. Similar results were observed: significant higher risks of hospital and 90-day mortality were found in BW group and SCr group but not in ABW or IBW group (Supplemental Digital Content 3 Table S4, http://links.lww.com/SHK/B326).

Consistently, logistic regression analyses demonstrated that ABW group was not linked to a different mortality compared with non-AKI group. In contrary, patients in BW group and SCr group were at significantly higher risks of hospital and 90-day death compared with those of the non-AKI group. Results were further confirmed in two separate sensitivity analyses where sepsis patients or patients with normal admission creatinine levels were considered.

DISCUSSION

In the current study, we examined the differences in hospital and 90-day mortality of critically ill patients diagnosed as AKI by SCr change or UO normalized by different definitions of body weight. ABW-normalized UO identified over 1,000 more AKI patients than IBW did, accounting for more than 8% of the whole cohort in our study. However, these patients had similar risks of hospital and 90-day mortality to those of patients with no evidence of AKI. Whereas AKI patients identified by SCr or by both ABW and IBW had twice higher the risks of hospital death and 1.5 times higher the risks of 90-day death respectively compared with non-AKI patients. Our results revealed that using ABW led to underestimate of patients' UO, subsequently overestimation of AKI.

There have been studies focusing on diagnosis of AKI by different definitions of body weight. Thongprayoon et al. (4) reported similar results in a single-center, retrospective study of 493 ICU patients. In their study, patients who had AKI according to ABW but not IBW had no significant increase in the risk of 90-day mortality. They concluded that ABW provided better sensitivity and earlier recognition of AKI and thus proposed that UO normalized by ABW should be used in clinical practice for screening purposes, while UO normalized by IBW should be used in research focusing on interventions for AKI patients. In another study by Katayama et al. (5) where 569 septic patients were studied, the authors found a discrepancy rate of 7.6% in terms of the urinary diagnosis of AKI by ABW and IBW, while no difference in 90-day mortality was found. However, in Thongprayoon's study, although baseline characteristics displayed in their paper included several basic demographics and comorbidities, the researchers failed to provide details about whether there were any differences in these factors, of which some were potential confounders, between subsets of patients. As a matter of fact, odds ratios the researchers reported were only adjusted by age and APACHE score, whereas BMI, which had apparently influence on odds ratios as mentioned in their paper, was not included. It is necessary to point out that in Katayama's study, sepsis patients identified by the Third International Consensus Definitions for Sepsis and Septic Shock (Sepsis-3) were

Table 3. **Characteristics and outcomes in defined groups**

	ABW and IBW	ABW	IBW	SCr	non-AKI	*P*
N	1,535	947	66	1,719	8,626	
Age	68 (58–78)	66 (57–75)	71 (56–81)	68 (57–77)	64 (52–75)	<0.001
Gender (male)	961 (62.6)	520 (54.9)	46 (69.7)	1,054 (61.3)	5,090 (59.0)	<0.001
Ethnicity						<0.001
Asian	16 (1.0)	6 (0.6)	7 (10.6)	48 (2.8)	224 (2.6)	
Black	78 (5.1)	42 (4.4)	2 (3.0)	98 (5.7)	580 (6.7)	
Hispanic	24 (1.6)	29 (3.1)	3 (4.5)	44 (2.6)	291 (3.4)	
White	289 (18.8)	166 (17.5)	8 (12.1)	307 (17.9)	1,356 (15.7)	
Other	1,128 (73.5)	704 (74.3)	46 (69.7)	1,222 (71.1)	6,175 (71.6)	
Admission Type						<0.001
Elective	298 (19.4)	245 (25.9)	16 (24.2)	488 (28.4)	1,575 (18.3)	
Emergency	1,182 (77.0)	670 (70.7)	47 (71.2)	1,174 (68.3)	6,799 (78.8)	
Urgent	55 (3.6)	32 (3.4)	3 (4.5)	57 (3.3)	252 (2.9)	<0.001
Height (cm)	173 (165–178)	170 (160–178)	175 (170–180)	170 (163–178)	170 (163–178)	<0.001
ABW (kg)	85 (73–100)	91 (81–105)	56 (50–63)	77 (67–90)	78 (66–90)	<0.001
IBW (kg)	73 (65–82)	73 (65–82)	70 (64–73)	68 (59–75)	68 (59–77)	<0.001
BMI (kg/m^2)	28.6 (24.7–33.4)	31.3 (27.8–36.2)	18.5 (17.5–20.1)	26.8 (23.8–30.7)	26.7 (23.5–30.5)	<0.001
Hospital Death	195 (12.7)	52 (5.5)	6 (9.1)	188 (10.9)	435 (5.0)	<0.001
90-day death	298 (19.4)	87 (9.2)	13 (19.7)	285 (16.6)	905 (10.5)	<0.001
LOS in ICU (days)	3.9 (2.2–7.2)	3.1 (1.9–5.9)	3.6 (2.2–6.9)	2.6 (1.5–4.9)	2.2 (1.4–3.8)	<0.001
Creatinine (mg/dL)						<0.001
Admission	1.0 (0.8–1.2)	0.9 (0.8–1.2)	0.9 (0.7–1.2)	0.9 (0.7–1.2)	0.9 (0.7–1.2)	
7-day minimum	0.7 (0.6–0.9)	0.7 (0.6–0.9)	0.7 (0.5–0.9)	0.8 (0.6–1.1)	0.7 (0.6–0.9)	
7-day maximum	1.1 (0.9–1.4)	1.0 (0.8–1.3)	1.0 (0.8–1.2)	1.4 (1.1–2.0)	1.0 (0.8–1.2)	
7-day change	0.3 (0.2–0.5)	0.3 (0.2–0.4)	0.3 (0.2–0.4)	0.5 (0.4–0.9)	0.3 (0.2–0.4)	
Comorbidities						
CHF	224 (14.6)	92 (9.7)	9 (13.6)	208 (12.1)	859 (10.0)	
Hypertension	11 (0.7)	8 (0.8)	1 (1.5)	18 (1.0)	71 (0.8)	0.819
Diabetes	473 (30.8)	305 (32.2)	6 (9.1)	462 (26.9)	1,925 (22.3)	<0.001
Cancer	130 (8.5)	54 (5.7)	8 (12.1)	124 (7.2)	666 (7.7)	0.062
Obesity	154 (10.0)	115 (12.1)	0 (0.0)	74 (4.3)	375 (4.3)	<0.001
Weightloss	59 (3.8)	21 (2.2)	6 (9.1)	50 (2.9)	290 (3.4)	0.013
SOFA score	4 (3–7)	4 (3–6)	5 (2–7)	5 (3–7)	3 (2–5)	<0.001
vasopressor Use	967 (63.0)	577 (60.9)	41 (62.1)	971 (56.5)	3,451 (40.0)	<0.001
Ventilation	1,182 (77.0)	765 (80.8)	54 (81.8)	1,194 (69.5)	4,659 (54.0)	<0.001
RRT	14 (0.9)	1 (0.1)	0 (0.0)	84 (4.9)	14 (0.2)	<0.001
First Lab tests						
WBC (1e9/L)	11.4 (8.3–15.8)	12.0 (8.7–15.7)	11.0 (8.1–14.3)	11.2 (8.1–15.4)	11.0 (7.9–14.8)	<0.001
Hematocrit (%)	36.0 (31.8–40.0)	36.3 (32.0–40.0)	35.7 (29.2–39.0)	34.9 (30.5–39.0)	36.0 (31.5–40.0)	<0.001
Sodium (mEq/L)	138 (136–140)	138 (136–141)	138 (134–140)	138 (135–140)	138 (136–140)	0.001
Potassium (mEq/L)	4.1 (3.8–4.5)	4.1 (3.8–4.4)	4.1 (3.9–4.5)	4.1 (3.7–4.5)	4.0 (3.7–4.4)	<0.001
Chloride (mEq/L)	104 (101–107)	104 (101–107)	103 (99–109)	105 (101–109)	104 (101–107)	<0.001
Bicarbonate (mEq/L)	24 (22–26)	24 (22–26)	24 (23–27)	23 (21–25)	24 (22–26)	<0.001
Anion Gap (mEq/L)	14 (11–16)	13 (11–15)	13 (12–16)	13 (11–16)	14 (11–16)	<0.001
BUN (mg/dL)	18 (14–26)	17 (13–23)	15 (13–23)	18 (13–27)	17 (12–23)	<0.001
Glucose (mg/dL)	129 (106–165)	128 (107–163)	111 (101–144)	123 (103–162)	124 (104–159)	<0.001

Continuous variables were presented as medians with interquartile ranges (25th–75th percentiles) and categorical variables as counts with percentages.
ABW indicates actual body weight; BMI, body mass index; BUN, blood urea nitrogen; CHF, chronic heart failure; IBW, ideal body weight; LOS, length of stay; RRT, renal replacement therapy; SCr, serum creatinine; SOFA, the sequential organ failure assessment; WBC, white blood cells.

studied (14), which explained the much higher 90-day mortality than that in Thongprayoon's and in our study. The limited sample size could also be the reason why no difference was found between patients diagnosed AKI by ABW and IBW in their study.

It is recommended in the KDIGO guidelines that invasive diagnostic workup be considered for stage 1 and above AKI patients, ICU admission and renal replacement therapy (RRT) for stage 2 and above (2). Given that invasive diagnostic approaches are rarely applied in clinical practice, even in the ICU settings, it is questionable that overdiagnosis of stage 1 AKI would be problematic. However, closer monitoring and more diagnostic tests are generally implemented when AKI is deemed to be present, meaning more medical resource demands and higher costs of care. This will be more common in stage 2 AKI patients when ICU admission and RRT are taken into consideration. With the coronavirus disease 2019 pandemic, health care professions have raised serious concerns that health care systems could be overwhelmed and additional financial support is urgently needed. Therefore, we argue that overdiagnosis of AKI is clinically relevant and deserves further investigation.

There are several limitations in our study. First, the retrospective nature of the current study should be addressed. Although we have tried our best to include all potential clinically relevant factors, other confounding factors not captured could not be ruled out. As the data came from a single-center academic tertiary medical center, generalizability of our results also remains to be further studied. And although our findings indicated that using ABW to diagnose AKI led to

Table 4. **Hospital and 90-day mortality risks of different patient groups**

	Hospital mortality			
Groups	Raw model*	Adjusted model*	Full model*	Reduced model*
IBW	1.88 (0.72–4.04)	1.18 (0.45–2.62)	1.06 (0.38–2.53)	1.06 (0.38–2.53)
ABW	1.09 (0.81–1.46)	1.33 (0.97–1.78)	1.25 (0.90–1.71)	1.24 (0.89–1.68)
BW	**2.74 (2.29–3.27)**	**2.88 (2.39–3.45)**	**2.26 (1.85–2.75)**	**2.22 (1.82–2.7)**
SCr	**2.31 (1.93–2.76)**	**2.26 (1.88–2.7)**	**1.99 (1.63–2.43)**	**1.94 (1.59–2.35)**
	90-day mortality			
	Raw model*	Adjusted model*	Full model*	Reduced model*
IBW	**2.09 (1.09–3.73)**	0.99 (0.50–1.81)	0.93 (0.45–1.81)	0.93 (0.45–1.81)
ABW	0.86 (0.68–1.08)	1.03 (0.81–1.30)	1.02 (0.79–1.31)	1.02 (0.79–1.30)
BW	**2.06 (1.78–2.37)**	**2.07 (1.78–2.40)**	**1.76 (1.49–2.07)**	**1.74 (1.48–2.05)**
SCr	**1.70 (1.47–1.96)**	**1.61 (1.39–1.86)**	**1.54 (1.31–1.81)**	**1.51 (1.29–1.77)**

95% confidence interval in brackets, bold texts indicates $P < 0.05$. All odds ratios are interpreted in comparison with the non-AKI group.
*The Raw model only contains the group variable. The Adjusted model contains the group variable, age, sex, and body mass index. The Full model contains the group variable and all other covariates described in Covariables in the Method section. And the Reduced model contains variables selected by the backwards step method based on the Akaike information criterion. Full results of all the models are provided in SupplementalDigitalContent1.xls.
ABW indicates actual body weight; BW, body weight; IBW, ideal body weight; SCr, serum creatinine.

overestimate of AKI and patients identified as AKI by ABW alone had similar hospital and 90-day mortality to those without evidence of AKI, causal relationship could not be established since data were not derived from a randomized controlled trial. However, our study included over 14,000 patients over a period of 10 years and results were confirmed in two sensitivity analyses. Given such a large sample size and findings held true in subsequent sensitivity analyses, our results are not likely to alter in future studies. Second, due to relatively small group size of the IBW group ($n = 66$), all statistical comparisons between IBW and another group tended to yield nonstatistically significant difference. However, to examine the difference between ABW and IBW-based AKI diagnosis, the best practice would be to separately consider patients identified as AKI by two different definitions of body weight. As a result, the use of IBW alone to calculate UO for AKI diagnosis was not fully studied in the current study and requires further investigation.

In summary, in this study, we found that using ABW to calculate UO for diagnosis of AKI resulted in underestimation of UO and overestimation of AKI.

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