Prevalence and Outcome of Acute Kidney Injury in the intensive care unit according to RIFLE criteria: A single-center study

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Abstract: Acute kidney injury (AKI) is common in the intensive care unit (ICU) and is associated with significant morbidity and mortality. This requires clinicians to be familiar with recent advances in definitions, diagnosis, prevention, and management of AKI in the ICU. The Acute Dialysis Quality Initiative (ADQI) represents the efforts of a workgroup seeking to develop consensus and evidence-based statements in the field of AKI. The ADQI group proposed a consensus graded definition, called the RIFLE criteria (Risk, Injury, Failure, Loss, and End stage). Objective: To estimate the prevalence of AKI in ICU and assess the ability of the RIFLE criteria to predict the outcome of AKI in ICU. Methods: We performed a retrospective cohort study in the internal medicine ICU, Zagazig University Hospital, in the period from January 2010 to December 2010. We excluded patients younger than 15 years, patients receiving chronic hemodialysis admitted to ICU, kidney transplant patients, length of hospital stays were <24 hours, or readmitted to the ICU during the study period. RIFLE criteria classified AKI patients into three stages of increasing severity Risk(R), Injury (I), and Failure (F). The outcomes of AKI patients in ICU were recovery, kidney loss, end stage renal disease (ESRD) or death. Results: The total number of ICU admissions during the study period was 8304 patients. After application of exclusion criteria, the number of the study became 5440 patients. According to RIFLE criteria 1885 (34.65%) had AKI. RIFLE criteria classified them into Risk 13.32%, Injury 11.91% and Failure 9.41%. The crude outcome of AKI patients as follow 77.24% recovered, 9% lost kidney functions and required renal replacement therapy (RRT), and 2.28% reached ESRD. The crude mortality of AKI patients was 20.47% versus 7.76% mortality in patients without AKI. The hospital recovery stratified by RIFLE criteria decreased with worsening RIFLE classes (R, I, F) 84.27%, 79.62% and 64.25% respectively. Patients' lost kidney functions and required RRT stratified by RIFLE criteria increased with worsening RIFLE classes 5.79%, 7.4% and15.62% respectively. Patients reached ESRD stratified by RIFLE criteria increased with worsening RIFLE classes 1.2%, 2% and 4.1% respectively. The hospital mortality AKI patients stratified by RIFLE criteria increased with worsening RIFLE classes 14.48%, 18.36% and 31.64% respectively. The urinary output (UOP) criteria associated with lower mortality and higher recovery rate than creatinine criteria. Conclusion: The prevalence of AKI in the internal medicine ICU, Zagazig University Hospital according to RIFLE criteria is 34.65%. RIFLE criteria are useful in predicting the outcome of AKI patients.
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1. Introduction:

Acute renal failure (ARF) has traditionally been defined as abrupt loss of kidney function that results in the retention of urea and other nitrogenous waste products and dysregulation of extracellular volume and electrolytes. The loss of kidney function is most easily detected by measurement of the serum creatinine (SCr) which is used to estimate the glomerular filtration rate (GFR) [1] ARF now increasingly referred to as AKI [2].The Acute Dialysis Quality Initiative convened in 2002 and proposed the RIFLE classification specifically for AKI in critically ill patients [3]. The most severe classification met by either criterion should be used. Of note, patients with primary kidney diseases such as glomerulonephritis were excluded from this definition [4]. The RIFLE classification is comprised of three stages of increasing severity, which correspond to risk (stage 1), injury (stage 2), and failure (stage 3). Loss and ESRD are removed from the staging system and defined as outcomes [5].

The cause of AKI in the ICU is commonly multi-factorial and frequently develops from a combination of hypovolemia, sepsis, medications, and hemodynamic perturbations. It is frequently not possible to isolate a single cause, thereby further complicating search for effective interventions in this complex disease process [6]. Sepsis is most common cause of AKI in a general ICU, accounting for up to 50% of cases [7], medications are also common cause of AKI [8]. Nearly all cases of ICU-associated AKI result from more than a single insult [9].

In the critically ill patient, the first kidney insult is often not predictable, therefore prevention of AKI

in the ICU often means prevention of a secondary insult in an at-risk patient [10]. Previous intervention and treatment trials have not had any significant impact on overall outcomes of patients with AKI [5], while in parallel; there is growing recognition of the strong association between the severity of AKI and subsequent morbidity and mortality, as well as costs during hospitalization [11] and in the longer term following hospital discharge [12].

AKI is a common clinical problem in ICU patients and typically portends an increase in morbidity and mortality [13].AKI occurs in approximately 7% of all hospitalized patients [14] and in up to 36% to 67% of critically ill patients depending on the definition used [9]. Based on 75,000 critically ill adults, more severe AKI occurs in 4% to 25% of all ICU admissions [15]. On average, 5% to 6% of ICU patients with AKI require renal replacement therapy RRT [16]. The true incidence of ESRD after AKI is unknown because epidemiologic studies do not routinely or consistently report rates of renal recovery [17].

Morbidity, a less appreciated consequence of AKI in the ICU, is associated with increased cost [11], increased length of stay [18] and increased risk of ESRD [19].

Reported mortality in ICU patients with AKI varies considerably between studies depending on AKI definition and the patient population studied. In the majority of studies, mortality increases proportionately with increasing severity of AKI [20].In patients with severe AKI requiring RRT, mortality is approximately 50% to 70% [21]. In a UK-based study, overall survival in 1,095 patients with severe AKI (serum creatinine >6.7 mg/dl) was 59%. Of these 16% remained on long-term dialysis [22]. In the French study, the mortality was 58%, and among the survivors, means serum creatinine was 2.6 mg/dl at the time of discharge from ICU [23].

While AKI requiring RRT in the ICU is a well-recognized independent risk factor for in-hospital mortality [11], even small changes in SCr are associated with increased mortality [24]. There is no current consensus on the indications for RRT in AKI. The only absolute indications for RRT in critically ill patients are metabolic acidosis, hypervolemia, and hyperkalemia that do not respond to other forms of therapy, although the early initiation of RRT might be beneficial in theory, data guiding the optimal timing of dialysis in patients with ARF is scarce [25]. We sought to estimate the prevalence of AKI in ICU and assess the ability of the RIFLE criteria to predict outcome in those patients.

2. Patients and Methods:

We constructed a retrospective cohort study on all adult hospitalizations during a 12 month in the period from January 2010 to 31 December 2010, at the internal medicine ICU of Zagazig University Hospital. All admitted patients were screened using the computerized hospital admissions and discharges database.

Exclusion criteria: Patients receiving chronic hemodialysis admitted to ICU or who had a kidney transplant, patients younger than 15 years, or if their length of hospital stays were <24 hours, and we only considered the first admission for patients who were readmitted to the ICU during the study period.

Demographic information: Collected from the database (age, gender, dates and source of admission, type of admission, intensive care unit admission, and hospital mortality.

Recording data: Primary diagnosis, presence of co morbidities, and need for mechanical ventilation. Physiologic data included Glasgow Coma Scale (GCS), vital signs, PaO2/FiO2 ratio, pH and serum electrolytes. Urine output was recorded at least once every one hour, and serum creatinine was measured at least once daily.

The RIFLE criteria diagnosed and classified our patients into [3]

RIFLE	SCr Criteria	UOP Criteria
Risk	1.5-fold increase in the SCr or *GFR decrease by 25%	<0.5 mL/kg per hour for 6 hours.
Injury	Twofold increase in the SCr or GFR decrease by 50 %	<0.5 mL/kg per hour for 12 hours.
Failure	Threefold increase in the SCr or GFR decrease by 75 %	<0.5 mL/kg per hour for 24 hours, or anuria for 12 hours.
Loss	Complete loss of kidney function (e.g., need for RRT) for > 4 weeks.	
ESRD	Complete loss of kidney function (e.g., need for RRT) for > 3 months.	

*GFR was measured by Cockroft-Gault formula: creatinine clearance (mL/min) = [(140 − age) × weight (kg)] / [72 × serum creatinine (mg/dL)] (×0.85 for women).

Prognosis of AKI:

1. Renal Recovery, either.

Complete renal recovery: Return of renal function to baseline

Partial renal recovery: Persistent change in RIFLE classification but not persistent need for RRT

2. Kidney loss:
3. ESRD:
4. Mortality: patients who died during the study.

The total numbers of ICU admissions during the study period were 8304 patients.

After application of exclusion criteria, the total number of the study became 5440 patients.

RIFLE criteria identified 1885 from studied patients suffered from AKI in different grades.

Their mean age was 56.02±13.7 (18-88) years.

Their gender 1035 "55 %" males and 850 "45 % "females

Time of AKI diagnosis: 55% of AKI patients were diagnosed on the day of admission and 45% developed AKI later during the periods of staying in ICU.

Co morbid disease: 575 (30.5%) from all AKI patients associated with other co morbid disease

Each of the severity classes (R, I, F) was reevaluated according to UOP criteria or SCr criteria and we choose the most severe classification met by either criterion

RIFLE criteria, classified AKI patients into Risk 725 patients (485 defined by SCr criteria and 240 defined by UOP criteria), Injury 648 patients (388 defined by SCr criteria and 260 defined by UOP criteria) and Failure 512 patients (308 defined by SCr criteria and 204 defined by UOP criteria)

Recorded hospital mortality in non AKI patients was 276 =7.76%.

Statistical Analysis

Data were collected, entered and checked to an SPSS version 15. Data were expressed as mean ± standard deviation and Chi square (χ^2) test was used for qualititative data to test the association between a factor exposure and outcome and Z test (test of proportion) was used for comparison of two proportions [26].

*P value of <0.05 was considered significant

3. Results:

The actual studied number was 5440 patients RIFLE criteria identified 1885 patients from a studied number suffered from AKI in different grades, so the prevalence of AKI in the ICU was 34.65%**.**

RIFLE criteria classified ICU patients into Risk 725 **(**13.32%**)**, Injury 648 **(**11.91%**)** and Failure 512 **(**9.41%**)**.

The crude outcome of AKI patients in our ICU: (Table 1)

The crude total recovery of all AKI patients 77.24%

The crude total lost kidney functions and required RRT of all AKI patients 9%

The crude ESRD of all AKI patients 2.28%

The crude mortality of all AKI patients 20.47%

Table (1): The crude outcome of AKI patients

	No	**%**
AKI patients	1885	= 34.65%
Recovery	1456	= 77.24%
Kidney loss "RRT"	170	= 9%
ESRD	43	= 2.28%
Mortality	386	= 20.47%

Natural history and Clinical outcomes stratified by RIFLE category: Figure (1)

Risk category: From725 patients165 patients initially recovered and the total end recovery 611 **(**84.27%**)** patients. 455 **(**62.75%**)** patients' progressed to the next stages, most of them recovered later, 42 **(**5.79%**)** patients lost kidney functions and required RRT and 9 **(**1.2%**)** patients reached ESRD. The remaining 105 **(**14.48%**)** patients died.

Injury category: From 648 patients 246 patients initially recovered and the total end recovery 516 **(**79.62%**)** patients. 285 **(**43.98%**)** patients' progressed to the next stages, most of them recovered later, 48 **(**7.4%**)** patients lost kidney functions and required RRT and 13 (2%) patients reached ESRD. The remaining119 **(**18.36%) patients died.

Failure category: From512 patients 270 patients initially recovered and the total end recovery 329 **(**64.25%**)** patients. 80 **(**15.62%**)** patients lost kidney functions and required RRT and 21 **(**4.1%**)** patients reached ESRD. The remaining 162 **(**31.64%**)** patients died.

Outcome comparison between RIFLE classes Table (2)

Recovery:

The recovery stratified by RIFLE criteria showed statistically significantly decrease with worsening RIFLE classes .P<0.001

Lost kidney function and RRT

Patients lost kidney functions and required RRT stratified by RIFLE criteria showed statistically significantly increase with worsening RIFLE classes. P<0.001

Patients end by ESRD

Patients reached ESRD stratified by RIFLE criteria showed statistically significantly increase with worsening RIFLE classes. P=0.003

Mortality:

The hospital mortality of AKI patients stratified by RIFLE criteria showed statistically significantly increase with worsening RIFLE classes .P<0.001

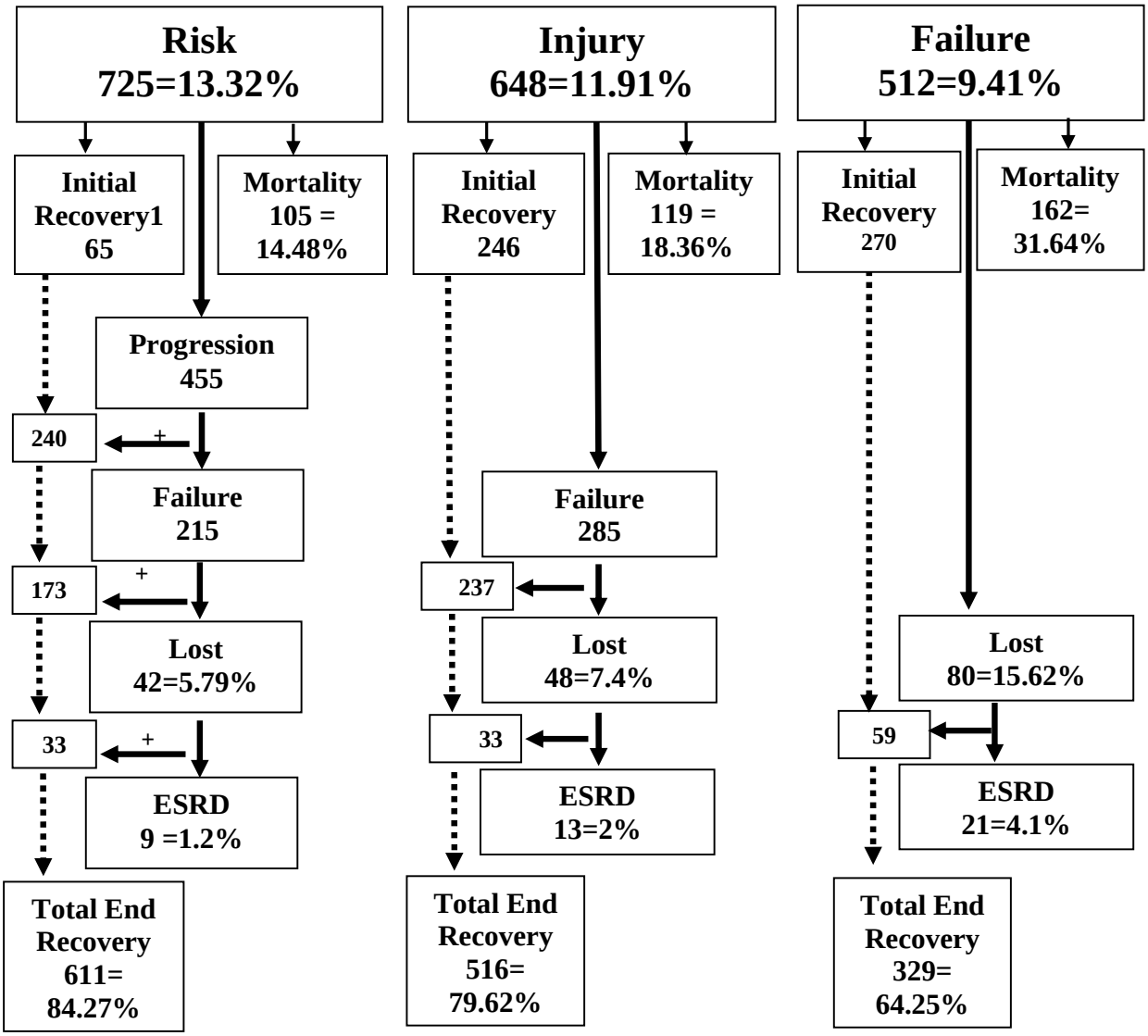

Figure (1) Natural history and Clinical outcomes stratified by RIFLE category

Table (2): Outcome comparison between different RIFLE classes

	Risk		Injury		Failure		X^2	P
	No	%	No	%	No	%		
Recovery	611	84.27%	516	79.62%	329	64.25%	71.61	<0.001
Loss (RRT)	42	5.79%	48	7.4%	80	15.62%	38.48	<0.001
ESRD	9	1.2%	13	2%	21	4.1%	11.35	0.003
Mortality	105	14.48%	119	18.36%	162	31.64%	56.96	<0.001

Table (3) : Mortality analysis among patients defined by serum creatinine versus urinary output criteria

	SCr	UOP
Number	1181	704
Mortality **%**	276 23.53%	110 15.62%
Z test. **P value**	2.35 <0.05	

Patients defined by creatinine criteria were associated with a statistically significantly higher mortality than those defined by UOP criteria. P<0.05

Table (4) : Mortality analysis stratified by RIFLE category between patients defined by serum creatinine versus urinary output criteria

	RISK		INJURY		FAILURE	
	SCr	**UOP**	**SCr**	**UOP**	**SCr**	**UOP**
Number (No)	485	240	388	260	308	204
Mortality No. **%**	79 16.28%	26 10.83%	84 21.64%	35 13.46%	113 36.68%	49 24.01%
Z test. **P value**	2.08 P<0.05		2.82 P<0.05		3.08 P<0.05	

In all RIFLE classes' patients defined by creatinine criteria were associated with a statistically significantly higher mortality than those defined by UOP criteria. P<0.05

Mortality analysis among patients with AKI versus those without AKI

Mortality was statistically significantly higher among patients with AKI 20.47% versus patients without AKI 7.76% [Z test=7.9, P <0.05]

Mortality analysis among patients with AKI alone versus those with other co morbid diseases

The total number of AKI patients with other co morbid diseases 575 (30.5%) patients from all AKI patients, classified as Risk 210 (36.52%), Injury 200 (34.78%) and Failure 165 (28.69%) patients.

The crude mortality of AKI patients with other co morbid diseases (40.69%)

Mortality was statistically significantly higher in patients with other co morbid diseases 40.69% versus those with AKI alone 11.6% [Z test13.04, P<0.05].

Table (5): Mortality analysis stratified by RIFLE classes among patients with AKI alone versus those with other co morbid diseases.

	RISK		INJURY		FAILURE	
	AKI alone	**Co-Morbid**	**AKI alone**	**Co-Morbid**	**AKI alone**	**Co-Morbid**
Total No.	515	210	448	200	347	165
Mortality. No. **%**	41 7.96%	64 30.47%	48 10.71%	71 35.5%	63 18.15%	99 60%
Z test. **P value**	6.64 P<0.05		6.29 P<0.05		9.46 P<0.05	

In all RIFLE classes mortality statistically significantly higher in AKI patients with other co morbid diseases versus those with AKI alone <0.05

4. Discussion

AKI previously termed ARF refers to a sudden decline in kidney function causing disturbances in fluid, electrolyte, and acid– base balance. More than 35 definitions of AKI currently exist [4].The Acute Dialysis Quality Initiative convened in 2002 and proposed the RIFLE classification, specifically for AKI in critically ill patients [3].AKI in the ICU is common, increasing in incidence [27] and is associated with a substantial increase in morbidity and mortality [28].There is limited information on whether the epidemiology of AKI in critically ill patients in different regions of the world has changed over time and there is controversy on whether its outcome has improved [29]. So we sought to estimate the prevalence of AKI in ICU and assess the ability

of the RIFLE criteria to predict the outcome in ICU patients.

The prevalence of AKI in the internal medicine ICU, Zagazig University Hospital was 34.65%, classified by RIFLE criteria into Risk, Injury and Failure.13.32%, 11.91%, and 9.41% respectively. Nearly similar results obtained by Bagshaw *et al.,* [30] who reported that AKI occurred in 36.1% of ICU patients and classified by RIFLE criteria R, I and F 16.2%, 13.6% and 6.3% respectively. Their study was done in 57 ICUs across Australia during a 5 year period and this may explain the slight difference in comparison to the current study. Also Ostermann *et al.,* [9] study reported the prevalence of AKI in 41.972 ICU patients was 35.8% and classified by RIFLE criteria R, I and F. 17.2%, 11 % and 7.6 %, respectively.

In contrary to our results Thakar *et al.,* [31] study found that the overall prevalence of AKI among patients admitted to Veterans Affairs ICUs including 71,486 patients the prevalence of AKI was 22%, however this difference can be explained by the fact that they studied patients who complicated by AKI during their stay in the intensive care unit. The lowest prevalence of the AKI in ICU reported by Brevet *et al.,* [23] was 7%, their study focused on the AKI occurring in the ICU in a 20 center, prospective 6 months performed in France in 1991, but this old study was carried for a short period and did not depend on RIFLE criteria for diagnosis of AKI. This low prevalence may explore the higher sensitivity of the RIFLE criteria for diagnosis of AKI and suggesting that the incidence of detectable AKI is annually increasing and much higher than previously appreciated.

The highest prevalence was reported by Hoste *et al.,* [28] was 67% ,with RIFLE classes R, I and F 28%, 27% and 12% respectively, they constructed a retrospective cohort study in seven ICUs serving medical, surgical, neurological, trauma and solid organ transplant patients during a 12 month period, this can be explained by the fact that their study was carried on different ICUs including surgical, neurological, trauma and solid organ transplant patients, expected to include high risk patients after surgery, trauma, hence they are more prone to AKI.

Regarding the progression of AKI to the next stages, the present study found that 62.75% of patients with RIFLE class R progressed to class I or class F, and more than 43.98% of the patients with RIFLE class I progressed to class F, this was compatible with the result obtained by Eric *et al.,* [32] study which found that more than 50% of patients with class R progressed to class I or class F, and more than one-third of the patients with class I progressed to class F.

The percentage of patients who lost kidney function and required RRT in this study were 9%, those patients when stratified by RIFLE criteria their percentages increase with worsening RIFLE classes 5.79%, 7.4% and15.62, respectively. Nearly similar results obtained by Eric *et al.,* [32] who found in their study patients requiring RRT classified by RIFLE criteria Risk, and Failure was 4.15% and 14.2% respectively. Also Shigehiko *et al.,* [33] who found among patients who survived to hospital discharge that 13.8% required RRT at the time of discharge. The small difference in results may relate to the argumentation in timing of initiation of RRT.

The percentage of patients who developed ESRD in this study was 2.4%; we also found when those patients stratified by RIFLE criteria their percentage increase with worsening RIFLE classes. R, I and F 1.2% , 2% and 4.1% respectively, although there is limited information about the percentage of patients ended by ESRD after AKI in ICU. However the similar results were obtained by Ostermann *et al.,* [9] study which found that 2.3% patients with AKI in ICU had developed ESRD.

Regarding mortality we found that the crude mortality of AKI patients in the ICU was 20.47%. Nearly similar results were obtained by Garzotto *et al.,* [34], who found that AKI mortality in the ICU was 21.7%. We also found that the hospital mortality AKI patients stratified by RIFLE criteria increased with worsening RIFLE classes 14.48%, 18.36% and 31.64% respectively. Similar results were obtained by Bagshaw *et al.,* [30] who found progressive increased in mortality from R, I to F 17.9%, 27.7% and 33.2% respectively, Eric *et al.,* [32] found progressive increased in mortality from R, I to F 8.8%, 11.4% and 26.3% respectively also many others studies confirmed our results as Hoste *et al.,* [15], Garzotto *et al.,*[34], Kuitunen *et al.,* [35], Ahlstrom *et al.,* [36], Uchino *et al.,* [37], Ricci *et al.,* [38], Ostermann *et al.,* [9] and Abosaif *et al.,* [39].

When we compared mortality among patients with AKI versus patients without AKI, we found that mortality in patients with AKI nearly 3 folds higher than patients without AKI 20.47% versus 7.76% respectively. Similar results obtained by many studies, Bagshaw *et al.,* [40] who found 24.2% versus 8.9% respectively and Eric et al [32] found ICU mortality rate stratified by RIFLE criteria R, I and F was 8.8%, 11.4% and 26.3%, respectively versus 5.5% for patients without AKI, also de Mendonça *et al.,* [41] found ICU mortality was 3 times higher in AKI patients than in other patients. Lastly Ricci *et al.,* [38] found among the 13 studies in which patient level data on mortality were available for patients without AKI; mortality was 6.9% in non-AKI patients versus 31.2% in AKI patients.

As an expecting we found that AKI patients with other co morbid diseases have worst mortality 40.69 % versus 11.6% for patients with AKI alone. Mortality also progressively increased with worsening RIFLE criteria R, I and F 30.47%, 33.55% and 60% respectively. Similar results obtained by de Mendonça *et al.,* [41] and Sirvent *et al.,* [42].

Interestingly when we compared the outcome among patients defined by SCr criteria versus those defined by UOP criteria, we found that UOP criteria carried a less mortality than SCr criteria, this mean that the UOP criteria had better predictive values than SCr criteria. These results matched with the results obtained by Eric *et al.,* [32] who reported that patients with class F based on SCr have a higher hospital mortality compared with patients having class F on UOP criteria. This result may be explained by the fact that SCr is not an early sensitive marker for AKI [1] and an early change in UOP may alarm for an early renal disease evoking early intervention. In contrary to our result Bagshaw *et al.,* [40] reported that mortality rates were higher in AKI patients defined by UOP criteria than in patients defined by SCr criteria but the modified UOP criteria used in that study may be responsible for this difference. As they defined AKI as an acute SCr level ≥ 133 µmol/l or a 24-hour UOP < 410 ml and not having received prior renal replacement therapy, these criteria different from the RIFLE criteria.

Conclusion

The prevalence of AKI in the Internal Medicine Zagazig University Hospital ICU is 34.65%. RIFLE criteria represent a simple and easy to use for the detection and classification of AKI on ICU admission and useful in predicting the outcome of AKI patients.

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References

Chertow, RL., 2003. Acute renal failure definitions and classification: time for change? J Am Soc Nephrol., 14:2178.

2. Molitoris BA, Levin A, Warnock DG, *et al.*,2007. Improving outcomes from acute kidney injury. J Am Soc Nephrol.; 18:1992.
3. Bellomo R, Ronco C, Kellum JA, *et al*.,2004. Acute renal failure— definition, outcome measures, animal models, fluid therapy and information technology needs: The Second International Consensus Conference of the Acute Dialysis Quality Initiative (ADQI) Group. Crit Care; 8:R204–R212.
4. Mehta RL and Chertow GM.,2003. Acute renal failure definitions and classification: Time for change? J Am Soc Nephrol., 14: 2178– 2187
5. Zacharias M, Conlon NP, Herbison GP *et al.*,2008. Interventions for protecting renal function in the perioperative period. Cochrane Database Syst Rev; CD003590.
6. Guerin C, Girard R, Selli JM, *et al.*,2000. Initial versus delayed acute renal failure in the intensive care unit. A multicenter prospective epidemiological study. Rhone-Alpes Area Study Group on Acute Renal Failure. Am J Respir Crit Care Med., 161: 872–879
7. Bagshaw SM, Uchino S, Bellomo R, *et al.*,2007. Septic acute kidney injury in critically Ill patients: Clinical characteristics and outcomes. Clin J Am Soc Nephrol., 2:431–439.
8. Uchino S, Kellum JA, Bellomo R, *et al.*,2005. Acute renal failure in critically ill patients: A multinational, multicenter study. Jama; 294:813–818.
9. Ostermann M. and Chang RW., 2007. Acute kidney injury in the intensive care unit
according to RIFLE. Crit Care Med., 35:1837–1843 54.
10. Wang Y, Cui Z. and Fan M., 2007. Hospital-acquired and community-acquired acute renal failure in hospitalized Chinese: A ten-year review .en Fail; 29:163–168.
11. Chertow GM, Burdick E, Honour M, *et al.*,2005. Acute kidney injury, mortality, length of stay, and costs in hospitalized patients. J Am Soc Nephrol., 16:3365–3370.
12. McCullough PA.,2008. Contrast induced acute kidney injury. J Am Coll Cardiol., 51: 1419–1428.
13. Uchino S, Kellum JA, Bellomo R, Doig GS, Morimatsu H, Morgera S, SchetzM, Tan I, Bouman C, Macedo E, *et al*.,2005. Acute renal failure in critically ill patients: a multinational, multicenter study. JAMA, 294:813-818.
14. Nash K, Hafeez A. and Hou S., 2002. Hospital-acquired renal insufficiency. Am J Kidney Dis., 39:930–936.
15. Hoste EA, Clermont G, Kersten A, *et al.,* 2006. RIFLE criteria for acute kidney injury are associated with hospital mortality in critically ill patients: A cohort analysis. Crit Care; 10:R73.
16. Mehta RL, Pascual MT, Gruta CG, *et al.*,2002. Refining predictive models in critically ill patients with acute renal failure. *J Am Soc Nephrol*; 13:1350- 1357
17. Macedo E, Bouchard J. and Mehta RL.,2008. Renal recovery following acute kidney injury. Curr Opin Crit Care; 14:660–665.
18. Harbrecht BG, Rosengart MR, Zenati MS, *et al.*,2007. Defining the contribution of renal dysfunction to outcome after traumatic injury. Am Surg; 73:836–840.

19. Liano F, Felipe C, Tenorio MT, *et al.*,2007. Longterm outcome of acute tubular necrosis: A contribution to its natural history. Kidney- Int; 71:679–686
20. Lopes JA, Jorge S, Resina C, *et al.,* 2007. Prognostic utility of RIFLE for acute renal failure in patients with sepsis. Crit Care; 11:408
21. Bagshaw SM, Laupland KB, Doig CJ, *et al.*,2005. Prognosis for long-term Survival and renal recovery in critically ill patients with severe acute renal failure: A population- based study. Crit Care; 9:R700–R709
22. Bhandari S and Turney JH., 1996. Survivors of acute renal failure who do not recover renal function.QJM; 89: 415–421
23. Brivet FG, Kleinknecht DJ, Loirat P, *et al.,* 1996. Acute renal failure in intensive care units – causes, outcome, and prog- nostic factors of hospital mortality; a prospective, multi- center study. French Study Group on Acute Renal Failure. Crit Care Med; 24: 192–198.
24. Coca SG, Peixoto AJ, Garg AX, *et al.,* 2007. The prognostic importance of a small acute decrement in kidney function in hospitalized patients: a systematic review and meta analysis. Am J Kidney Dis., 50:712–720.
25. Liu KD, Himmelfarb J, Paganini E; *et al.,* 2006. Timing of initiation of dialysis in critically ill patients with acute kidney injury. Clin J Am Soc Nephrol. ; 1(5):915-919.
26. Dean A, Dean J, and Brenddle K., 2004. Epi-Info version 6.02 a word Processing data base and statistics program for epidemiology.
27. Collins AJ, Foley R, Herzog C, *et al.,* 2008. Excerpts from the United States Renal Data System 2007 annual data report. Am J Kidney Dis., 51:S1–S320
28. Hoste EA, Blot SI, Lameire NH, *et al.*,2004. Effect of noso- comial bloodstream infection on the outcome of critically ill patients with acute renal failure treated with renal replace- ment therapy. J Am Soc Nephrol., 15: 454–462.
29. Bagshaw SM, Laupland KB, Doig CJ, Mortis G, Fick GH, Mucenski M, Godinez-Luna T, Svenson LW and Rosenal T., 2005. Prognosis for longterm survival and renal recovery in critically ill patients with severe acute renal failure: a population-based study. Crit Care, 9:R700-R709.
30. Bagshaw SM,Carol George, Irina Dinu and Rinaldo Bellomo, 2008. A multi-centre evaluation of the RIFLE criteria for early acute kidney injury in critically illpatients' .Nephrol Dial Transplant 23: 1203–1210 doi: 10.1093/ndt/gfm744
31. Thakar CV, Christianson A, Freyberg R, Almenoff P. and Render ML., 2009. Incidence and outcomes of acute kidney injury in intensive care units: a Veterans Administration study. Crit Care Med. 37:2552-8.
32. Eric AJ Hoste1, Gilles Clermont1, Alexan Kersten1RameshVenkataraman, Derek C Angus1, Dirk De Bacquer and John A Kellum, 2006. RIFLE criteria for acute kidney injury are associated with hospital mortality in critically ill patients: a cohort analysis .Critical Care, 10:R73 .
33.Shigehiko Uchino,John A. Kellum,Rinaldo Bellomo, Gordon S. Doig, Morimatsu, ,Stanislao Morgera, ,Miet Schetz, ,Ian Tan ,Catherine Bouman, Ettiene Macedo,Noel Gibney, ,Ashita Tolwani. and Claudio Ronco, 2005. Acute Renal Failure in Critically Ill Patients A Multinational,Multicenter Study. JAMA. *; 294:813-818*
34.Garzotto F, Piccinni P, Cruz D, Gramaticopolo S, Dal Santo M, Aneloni G, Kim JC, Rocco M, Alessandri E, Giunta F, Michetti V, Iannuzzi M, Belluomo Anello C, Brienza N, Carlini M, Pelaia P, Gabbanelli V and Ronco C.,2011. NEFROINT investigation group. RIFLE-based data collection/management system applied to a prospective cohort multicenter Italian study on the epidemiology of acute kidney injury in the intensive care unit. Blood Purif. , 31:159-71.
35. Kuitunen A, Vento A, Suojaranta-Ylinen R, *et al.*,2006. Acute renal failure after Cardiac surgery: Evaluation of the RIFLE classification. Ann Thorac Surg., 81:542–546
36. Ahlstrom A, Kuitunen A, Peltonen S, *et al.,* 2006. Comparison of 2 acute renal failure Severity scores to general scoring systems in the critically ill. Am J Kidney Dis., 48:262–268 5747.
37. Uchino S, Bellomo R, Goldsmith D, *et al.*,2006. An assessment of the RIFLE criteria for acute renal failure in hospitalized patients. Crit Care Med; 34:1913–1917
38. Ricci, D Cruz and C Ronco, 2008. The RIFLE criteria and mortality in acute kidney injury: A systematic review. Kidney International, 73: 538.
39. Abosaif NY, Tolba YA, Heap M., *et al.,* 2005. The outcome of acute renal failure in the Intensive care unit according to RIFLE: Model application, sensitivity, and predictability. Am J Kidney Dis., 46:1038 –1048
40. Bagshaw SM, George C, Dinu I, Bellomo R.,2008. Studies on AKI using RIFLE criteria. Nephrol Dial Transplant. Oxford University Press. 23:1203-1210.
41. de Mendonça A, Vincent JL, Suter PM, Moreno R, Dearden NM, Antonelli M, Takala J, Sprung C. and Cantraine F., 2000. Acute renal failure in the ICU: risk factors and outcome evaluated by the SOFA score .Intensive Care Med.,26:915-21.
42.Sirvent JM, Vallés M, Navas E, Calabia J, Ortiz P. and Bonet A.,2010. Outcome of critically ill patients with acute renal failure and multiple organ failure treated with continuous venovenous haemodiafiltration. Med Intensiva.;34:95-101.

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