The long-term outcome after acute kidney injury: a narrative review

Evolução em longo prazo após episódio de lesão renal aguda: revisão narrativa

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Abstract

This review will focus on long-term outcomes after acute kidney injury (AKI). Surviving AKI patients have a higher late mortality compared with those admitted without AKI. Recent studies have claimed that long-term mortality in patients after AKI varied from 15% to 74% and older age, presence of previous co-morbidities, and the incomplete recovery of renal function have been identified as risk factors for reduced survival. AKI is also associated with progression to chronic kidney (CKD) disease and the decline of renal function at hospital discharge and the number and severity of AKI episodes have been associated with progression to CKD. IN the most studies, recovery of renal function is defined as non-dependence on renal replacement therapy which is probably too simplistic and it is expected in 60-70% of survivors by 90 days. Further studies are needed to explore the long-term prognosis of AKI patients.

Keywords: acute kidney injury; clinical evolution; fatal outcome; mortality; recovery of function.

Resumo

Esta revisão tem como objetivo focar o prognóstico em longo prazo de pacientes após episódio de lesão renal aguda (LRA). Pacientes sobreviventes à LRA apresentam maior mortalidade tardia quando comparados com aqueles internados sem LRA. Estudos recentes mostram mortalidade em logo prazo após LRA entre 15 e 74% e, de modo geral, são fatores que contribuem para essa mortalidade a idade avançada, a presença de comorbidades preexistentes e a recuperação incompleta da função renal. LRA também está associada com evolução para doença renal crônica, sendo a queda de função renal na alta hospitalar e número e intensidade dos episódios de LRA fatores associados com a evolução para DRC. A recuperação da função renal é definida pela maioria dos estudos como a não dependência de diálise e ocorre em 60 a 70% dos pacientes em até 90 dias. Futuros estudos são necessários para explorar o prognóstico tardio desses pacientes.

Palavras-chave: evolução clínica; evolução fatal; lesão renal aguda; mortalidade; recuperação de função fisiológica.

Introduction

Traditionally, most studies of severe acute kidney injury (AKI) in the critically ill have focused on short-term outcomes often assessed at hospital discharge. The risk of mortality associated with AKI is decreasing, but this mortality remains unacceptably high.[1,2] Still, severe AKI should no longer simply be viewed as an indicator of overall severity of illness, but rather the failing kidney can exhibit important independent effects on outcome that may extend well beyond discharge from hospital.[3] Thus, this review will focus on the long-term outcomes from AKI in the critically ill with an emphasis on survival and renal recovery.

In order to detect recent publications (2000 to present) on long-term outcome after AKI, an extensive literature search was performed using the Pubmed and MEDLINE. The key search terms used were acute kidney injury, long-term, mortality, renal recovery and prognosis,

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alone and in combination. All articles identified were English-language, full-text papers. We also searched the reference lists of identified articles for further relevant papers.

Long-term mortality

Several studies have documented the long-term survival after severe AKI, in particular when coupled with admission to an ICU. Many studies reporting long-term outcome have limited generalizability as a result of selection bias due to inclusion of patients from a single institution, from either medical or surgical ICUs, or non-critically ill patients. Similarly, many of these studies were small or retrospective in design. Only one study was systematic review. Further, the development of severe AKI that would otherwise necessitate initiation of RRT can significantly influence decisions for life support withdrawal that can bias true estimates of mortality.[4]

These factors contribute to the notable differences in long-term mortality rates across studies and thus need to be considered when making inferences regarding long term survival.

Survival rates post-discharge from 90 days to 10 years have been reported in almost 30 studies and ranged from 15-74%.[5-33] At 90 days, the estimated mortality was 45-74%,[5-10,16-20] but when restricted to critically ill patients was approximately 60%.[5-8,16-20] In a population based study of all episodes of severe AKI requiring RRT in all ICUs from a single health region, Bagshaw *et al*.[5] estimated a 90-day mortality of 60%. At 6 months, the cumulative mortality has been reported between 55 and 73%.[7-9] In a large retrospective study, Morgera *et al*.[10] reported the long-term outcomes in a cohort of critically ill patients with severe AKI requiring RRT. The hospital mortality was 69%, and the probability of survival in the first 6 months after discharge was 77%. Estimates of mortality at 1 year have ranged from 15 to 65%.[5-12] Stevens *et al*.[29] found 2-year and 3-year mortality rates of 69% and 72%, respectively. Recently, Gallagher *et al*.[14] reported that there is no effect of differing RRT modalities on long-term outcome of AKI. At 2 and 3 years, 62% and 63% of patients had died in the lower and higher intensity dialysis groups, respectively (RR 1.04, 95% CI 0.96-1.12, p = 0.49). With follow- up to 5 years after admission to ICU, death had occurred in 55-70% of those diagnosed with severe AKI.[8,17,20,25] Schiffl *et al*.[17] followed up 226 patients with severe AKI, (defined as need for dialysis) and absence of previous CKD and the observed mortality rate was 75% after 5 years, while Liano *et al*.[15] evaluated 177 patients surviving a moderate or severe acute tubular necrosis (ATN) episode and 50% were alive 10 years later. The difference in mortality depends on the setting and time period studied, and the severity of AKI.

Few studies have specifically assessed factors predictive of long-term survival.[5-7,10,11,15,17,27,28] Non-modifiable factors at admission to ICU, such as older age and high burden of co-morbid illness, specifically advanced cirrhosis, have been associated with increased risk of death following an episode of AKI.[5-7,10,11,15,28] Likewise, greater severity of illness, as assessed by APACHEII or SOFA scores, and concomitant septic shock have been independently associated with death.[5-7,10,15,17] Recent studies have suggested that long-term survival is associated with pre-existing chronic conditions and not with the severety of AKI episode.[11,27] The failure to recover to baseline kidney function and the progression to chronic kidney disease has been associated with reduced survival in some studies.[18,27,34-36] While some studies[5,7] have suggested that use of continuous renal replacement therapy independently predicted death, this has not universally been found.[8,20,34,36] Higher intensity of prescribed RRT has not been suggested to improve long-term outcome.[14]

In summary, the factors that contribute to AKI-associated mortality vary with time and differ in the early and long-term. Factors that modify the risk of early mortality occurring in less than 90 days after AKI include the primary diagnosis (such as sepsis), severity of acute illness and the burden of acute nonrenal organ dysfunction. Among early survivors, factors contributing to intermediate and long-term mortality include older age, pre-existing comorbid disease (CKD, cardiovascular disease or malignancy) and incomplete organ recovery with ongoing residual disease (Table 1).

Recovery of renal function

Nonrecovery of kidney function following an episode of AKI is a major morbid event with long-term implications for patients and health resources. The long term rates for complete or partial recovery of function are not well described and data related to the progression to chronic kidney disease (CKD) are

Table 1 Factors independently associated with early (< 90 days) and long-term mortality (> 90 days) after acute kidney injury episode

Factors associated with early (A) and long-term (B) mortality	References
-severe sepsis/septic shock (A,B)	1-9, 16, 24
-older age (A,B)	2,5-11, 33
-higher severity of illness (A,B)	10-21, 32
-pre existing diseases (CKD, CV or malignancy) (A,B)	11, 14-17
-APACHE II, RIFLE or SOFA (A)	9-12, 24-26
-RRT ? (A,B)	23-27
- incomplete recovery of kidney function (B)	18-23

RRT: Renal replacement therapy; CKD: Chronic kidney disease; CV: Cardiovascular disease.

conflicting. Data from studies including all etiologies of AKI are difficult to interpret as functional prognosis is known to be worse in some types of glomerulonephritis or vasculitis.

No consensus on a definition of renal recovery after AKI exists. The most frequent definitions are the weaning from dialysis, normalization of serum creatinine (sCr) or return to sCr baseline value. These criteria are associated with different rates of renal recovery depending on the cohort being evaluated. Studies including only dialyzed patients and considering recovery as weaning from dialysis can show higher rates of recovery than those evaluating patients with AKI based on baseline sCr. In addition, most of the studies left the ultimate decision to stop dialysis at the discretion of the treating physician, creating an outcome that is strongly influenced by individual physician and center practice patterns. These disparities in renal recovery definition are reflected on the different rates of reported renal recovery.

In large observational cohort studies of critically ill patients with severe ATN requiring RRT, the rate of dialysis dependence at hospital discharge was 13-29%.[2,5,37,38]

Among survivors of AKI, the rate of dialysis dependence seems to decrease at 6 months and 12 months after AKI onset; however, this result is often confounded by deaths that occur predominantly among those patients who remain on dialysis.[5,20]

Several patient-level susceptibilities modify the likelihood of nonrecovery from AKI and rapid progression to end stage renal disease (ESRD), in particular older age,[36-38] severity of CKD at baseline, female sex, presence of co-morbidities, parenchymal etiology of AKI, and late initiation of renal replacement therapy (RRT) or use of conventional intermittent RRT have all been associated with reduced recovery[5,8,21,25,38-43] (Table 2). Both the severity of AKI and the number of AKI episodes are also associated with the development of incident CKD and ESRD.[18,39] However, no studies have specifically addressed what factors are predictive of long-term recovery of function.

Table 2 Factors associated with non renal recovery after an acute kidney injury episode

Factors	References
Older age	2, 5, 35-38
Severity of CKD	8, 21, 25
Severity of AKI	39-43
Number of AKI episodes	11, 17, 18
Female sex	5, 33
Presence of comorbidities	10, 14-17
Parenchimal etiology of AKI	8, 21
RRT?	21-25
Late initiation of RRT	39
Intermittent RRT	12, 21

CKD: Chronic kidney disease; AKI: Acute kidney injury; RRT: Renal replacement therapy.

Although no validated scoring systems that reliably predict recovery of kidney function after AKI are currently available, much effort is being focused on biomarkers of AKI that can make the diagnosis earlier and more accurately and possibly enable the use of strategies to prevent progression of this syndrome.[42] In an experimental study in rats, ongoing inflammation and immune activity were found to be involved with the pathogenesis of CKD, and NGAL was upregulated, suggesting that it may be a valuable biomarker for the development of CKD after AKI.[43] In addition, recent evidence suggests that NGAL may even be involved as a mediator of CKD progression.[44]

Incident CKD and progression to ESRD

AKI is an independent risk for incident CKD and progression to ESRD[44-47] and the severity of AKI has been associated with recovery of renal function at the time of hospital discharge and progression to CKD. Studies performed by Pereira *et al.*[11] and Chawla

et al.[45] showed that older age and the severity of AKI predicted progression to CKD. The most severe AKI patients evaluated by the RIFLE or AKIN criteria presented lower rate of recovery of renal function at the time of hospital discharge and higher progression to CKD. The risk of incident ESRD is reported to be 2.7-fold higher among critically ill patients with AKI who do not require RRT than among patients without AKI.[36] These patients are also at increased risk of major cardiovascular events, rehospitalization and mortality.[35,43]

Depending on the AKI etiology, 3-41% of patients could have end-stage renal disease and 3-24% could need chronic dialysis after discharge.[36] The US Renal Data System 2010 Annual Data Report indicates that survivors of AKI are at risk of developing ESRD within the following year. This risk increases from less than 1% for those without previous CKD to 5% for those with previous CKD.[46]

Brito *et al.*[27] described that the need for chronic dialysis was present in 4.7% after 60 months of follow up and all patients who progressed toward ESRD had previous CKD. Similar results were recently observed by Macedo *et al.*[18] showing that 4.7% progressed to ESRD; however, only one (1.1%) did so within the first year after AKI. In general, studies suggest a low rate of long term recurring need for RRT in those surviving an episode of critical illness, specifically with prior normal kidney function.

The risk of progression to CKD was higher in patients with previous CKD [glomerular filtration rate (GFR < 60 ml/min)] than those without it (GFR > 60 ml/min). In study of Brito *et al.*[27] less than 9% of patients without previous CKD progressed to CKD Stages 4 or 5 while 23% of patients with previous CKD progressed to CKD Stages 4 or 5. These results are similar to that found by Amdur *et al.*[47] where 20% of those with ATN progressed to CKD stage 4 or 5. Wu *et al.*[19] evaluated 9425 patients after severe AKI (with need for dialysis) and patients with previous CKD presented higher risk of progression to ESRD when compared with patients without previous CKD (17.8 x 0.15 patients/year). The risk of progression to ESRD was also higher when patients with previous CKD did not have total recovery of renal function at hospital discharge (RR = 212.7, 95% CI 105.5-428.8, $p < 0.001$).

Thakar *et al.*[39] studied patients with diabetes and risk of progression to CKD after ATN episodes. It was observed that an episode of AKI in diabetic patients compared with diabetic patients without ATN was associated with progression to CKD Stage 4 (RR = 3.56, 95% CI 2.76-4.61), and that each new episode of AKI led to increased risk (RR = 2.02, CI = 1.78-2.3).

In summary, progression to CKD is common and is associated with older age, presence of previous CKD and severity of AKI (Table 3).

Table 3 Factors associated with chronic kidney disease and progression to end stage renal disease after acute kidney injury episode

Factors	References
Older age	27,36
Severity of CKD	46-49
Severity of AKI (?)	33-37,46-49
Number of AKI episodes	36,47,48
Presence of comorbidities	36, 40-43, 46-48
RRT?	27, 36,46-49

CKD: Chronic kidney disease; AKI: Acute kidney injury; RRT: Renal replacement therapy.

Conclusion

It is increasingly recognized that AKI should not only be considered an acute syndrome, but it can be a risk condition for progression of CKD and late mortality. Several studies confirm that the long-term survival for patients with critical illness characterized by severe AKI is generally poor. Those who do survive, however, by and large enjoy high rates of renal recovery to independence from RRT. The long-term rates for complete or partial recovery of function are less well described and because of this the survivors of AKI deserve a careful and long-term medical follow-up. Further research is needed to explore the relationship between long-term survival and subsequent morbidity, specifically considering the recovery of kidney function.

References

1. Susantitaphong P, Cruz DN, Cerda J, Abulfaraj M, Alqahtani F, Koulouridis I. et al.; Acute Kidney Injury Advisory Group of the American Society of Nephrology. World incidence of AKI: a meta-analysis. Clin J Am Soc Nephrol 2013;8:1482-93. DOI: http://dx.doi.org/10.2215/CJN.00710113
2. Uchino S, Kellum JA, Bellomo R, Doig GS, Morimatsu H, Morgera S, et al.; Beginning and Ending Supportive Therapy for the Kidney (BEST Kidney) Investigators. Acute renal failure in critically ill patients: a multinational, multicenter study. JAMA 2005;294:813-8. PMID: 16106006 DOI: http://dx.doi.org/10.1001/jama.294.7.813

3. Rewa O, Bagshaw SM. Acute kidney injury-epidemiology, outcomes and economics. Nat Rev Nephrol 2014;10:193-207. DOI: http://dx.doi.org/10.1038/nrneph.2013.282
4. Swartz R, Perry E, Daley J. The frequency of withdrawal from acute care is impacted by severe acute renal failure. J Palliat Med 2004;7:676-82. DOI: http://dx.doi.org/10.1089/jpm.2004.7.676
5. Bagshaw SM, Laupland KB, Doig CJ, Mortis G, Fick GH, Mucenski M, et al. Prognosis for long-term survival and renal recovery in critically ill patients with severe acute renal failure: a population-based study. Crit Care 2005;9:R700-9. DOI: http://dx.doi.org/10.1186/cc3879
6. Bagshaw SM, Mortis G, Doig CJ, Godinez-Luna T, Fick GH, Laupland KB. One-year mortality in critically ill patients by severity of kidney dysfunction: a population-based assessment. Am J Kidney Dis 2006;48:402-9. PMID: 16931213 DOI: http://dx.doi.org/10.1053/j.ajkd.2006.06.002
7. Ahlström A, Tallgren M, Peltonen S, Räsänen P, Pettilä V. Survival and quality of life of patients requiring acute renal replacement therapy. Intensive Care Med 2005;31:1222-8. DOI: http://dx.doi.org/10.1007/s00134-005-2681-6
8. Korkeila M, Ruokonen E, Takala J. Costs of care, long--term prognosis and quality of life in patients requiring renal replacement therapy during intensive care. Intensive Care Med 2000;26:1824-31. DOI: http://dx.doi.org/10.1007/s001340000726
9. Van Berendoncks AM, Elseviers MM, Lins RL; SHARF Study Group. Outcome of acute kidney injury with different treatment options: long-term follow-up. Clin J Am Soc Nephrol 2010;5:1755-62. DOI: http://dx.doi.org/10.2215/CJN.00770110
10. Morgera S, Kraft AK, Siebert G, Luft FC, Neumayer HH. Long-term outcomes in acute renal failure patients treated with continuous renal replacement therapies. Am J Kidney Dis 2002;40:275-9. PMID: 12148099 DOI: http://dx.doi.org/10.1053/ajkd.2002.34505
11. Pereira MB, Zanetta DM, Abdulkader RC. The real importance of pre-existing comorbidities on long-term mortality after acute kidney injury. PLoS One 2012;7:e47746. DOI: http://dx.doi.org/10.1371/journal.pone.0047746
12. Schiffl H. Renal recovery from acute tubular necrosis requiring renal replacement therapy: a prospective study in critically ill patients. Nephrol Dial Transplant 2006;21:1248-52. DOI: http://dx.doi.org/10.1093/ndt/gfk069
13. Loef BG, Epema AH, Smilde TD, Henning RH, Ebels T, Navis G, et al. Immediate postoperative renal function deterioration in cardiac surgical patients predicts in-hospital mortality and long-term survival. J Am Soc Nephrol 2005;16:195-200. DOI: http://dx.doi.org/10.1681/ASN.2003100875
14. Gallagher M, Cass A, Bellomo R, Finfer S, Gattas D, Lee J, et al.; POST-RENAL Study Investigators and the ANZICS Clinical Trials Group. Long-term survival and dialysis dependency following acute kidney injury in intensive care: extended follow-up of a randomized controlled trial. PLoS Med 2014;11:e1001601. DOI: http://dx.doi.org/10.1371/journal.pmed.1001601
15. Liaño F, Felipe C, Tenorio MT, Rivera M, Abraira V, Sáez-de--Urturi JM, et al. Long-term outcome of acute tubular necrosis: a contribution to its natural history. Kidney Int 2007;71:679-86. PMID: 17264879 DOI: http://dx.doi.org/10.1038/sj.ki.5002086
16. Ponte B, Felipe C, Muriel A, Tenorio MT, Liaño F Long-term functional evolution after an acute kidney injury: a 10-year study. Nephrol Dial Transplant 2008;23:3859-66. DOI: http://dx.doi.org/10.1093/ndt/gfn398
17. Schiffl H, Fischer R. Five-year outcomes of severe acute kidney injury requiring renal replacement therapy. Nephrol Dial Transplant 2008;23:2235-41. DOI: http://dx.doi.org/10.1093/ndt/gfn182
18. Macedo E, Zanetta DM, Abdulkader RC. Long-term follow--up of patients after acute kidney injury: patterns of renal functional recovery. PLoS One 2012;7:e36388. DOI: http://dx.doi.org/10.1371/journal.pone.0036388
19. Wu VC, Huang TM, Lai CF, Shiao CC, Lin YF, Chu TS, et al. Acute-on-chronic kidney injury at hospital discharge is associated with long-term dialysis and mortality. Kidney Int 2011;80:1222-30. PMID: 21832983 DOI: http://dx.doi.org/10.1038/ki.2011.259
20. Lafrance JP, Miller DR. Acute kidney injury associates with increased long-term mortality. J Am Soc Nephrol 2010;21:345-52. DOI: http://dx.doi.org/10.1681/ASN.2009060636
21. Triverio PA, Martin PY, Romand J, Pugin J, Perneger T, Saudan P. Long-term prognosis after acute kidney injury requiring renal replacement therapy. Nephrol Dial Transplant 2009;24:2186-9. DOI: http://dx.doi.org/10.1093/ndt/gfp072
22. Liu KD. Acute kidney injury: is acute kidney injury a risk factor for long-term mortality? Nat Rev Nephrol 2010;6:389-91.
23. Goldberg A, Kogan E, Hammerman H, Markiewicz W, Aronson D. The impact of transient and persistent acute kidney injury on long-term outcomes after acute myocardial infarction. Kidney Int 2009;76:900-6. PMID: 19657321 DOI: http://dx.doi.org/10.1038/ki.2009.295
24. Hsu CY, Chertow GM, McCulloch CE, Fan D, Ordoñez JD, Go AS Nonrecovery of kidney function and death after acute on chronic renal failure. Clin J Am Soc Nephrol 2009;4:891-8. DOI: http://dx.doi.org/10.2215/CJN.05571008
25. Tsagalis G, Akrivos T, Alevizaki M, Manios E, Theodorakis M, Laggouranis A, et al. Long-term prognosis of acute kidney injury after first acute stroke. Clin J Am Soc Nephrol 2009;4:616-22. DOI: http://dx.doi.org/10.2215/CJN.04110808
26. Van Berendoncks AM, Elseviers MM, Lins RL; SHARF Study Group. Outcome of acute kidney injury with different treatment options: long-term follow-up. Clin J Am Soc Nephrol 2010;5:1755-62. DOI: http://dx.doi.org/10.2215/CJN.00770110
27. Brito GA, Balbi AL, Abrão JM, Ponce D. Long-term outcome of patients followed by nephrologists after an acute tubular necrosis episode. Int J Nephrol 2012;2012:361528. PMID: 23227335 DOI: http://dx.doi.org/10.1155/2012/361528
28. Gammelager H, Christiansen CF, Johansen MB, Tønnesen E, Jespersen B, Sørensen HT. Five-year risk of end-stage renal disease among intensive care patients surviving dialysis-requiring acute kidney injury: a nationwide cohort study. Crit Care 2013;17(4):R145. DOI: http://dx.doi.org/10.1186/cc12824
29. Stevens PE, Tamimi NA, Al-Hasani MK, Mikhail AI, Kearney E, Lapworth R, et al. Non-specialist management of acute renal failure. QJM 2001;94:533-40. PMID: 11588212 DOI: http://dx.doi.org/10.1093/qjmed/94.10.533
30. Hoste EA, De Corte W. AKI patients have worse long-term outcomes, especially in the immediate post-ICU period. Crit Care 2012;16:148. DOI: http://dx.doi.org/10.1186/cc11470
31. Lopez-Delgado JC, Esteve F, Torrado H, Rodríguez-Castro D, Carrio ML, Farrero E, et al. Influence of acute kidney injury on short- and long-term outcomes in patients undergoing cardiac surgery: risk factors and prognostic value of a modified RIFLE classification. Crit Care 2013;17:R293. DOI: http://dx.doi.org/10.1186/cc13159
32. Nisula S, Vaara ST, Kaukonen KM, Reinikainen M, Koivisto SP, Inkinen O, et al.; FINNAKI-QOL Study Group. Six-month survival and quality of life of intensive care patients with acute kidney injury. Crit Care 2013;17:R250. DOI: http://dx.doi.org/10.1186/cc13076
33. Ng KP, Chanouzas D, Fallouh B, Baharani J. Short and long--term outcome of patients with severe acute kidney injury requiring renal replacement therapy. QJM 2012;105:33-9. DOI: http://dx.doi.org/10.1093/qjmed/hcr133
34. Swartz RD, Bustami RT, Daley JM, Gillespie BW, Port FK. Estimating the impact of renal replacement therapy choice on outcome in severe acute renal failure. Clin Nephrol 2005;63:335-45. PMID: 15909592 DOI: http://dx.doi.org/10.5414/CNP63335
35. Wehbe E, Duncan AE, Dar G, Budev M, Stephany B. Recovery from AKI and short- and long-term outcomes after lung transplantation. Clin J Am Soc Nephrol 2013;8:19-25. DOI: http://dx.doi.org/10.2215/CJN.04800512

36. Coca SG, Singanamala S, Parikh CR. Chronic kidney disease after acute kidney injury: a systematic review and meta-analysis. Kidney Int 2012;81:442-8. PMID: 22113526 DOI: http://dx.doi.org/10.1038/ki.2011.379
37. Bell M, SWING, Granath F, Schön S, Ekbom A, Martling CR. Continuous renal replacement therapy is associated with less chronic renal failure than intermittent haemodialysis after acute renal failure. Intensive Care Med 2007;33:773-80. DOI: http://dx.doi.org/10.1007/s00134-007-0590-6
38. Silvester W, Bellomo R, Cole L. Epidemiology, management, and outcome of severe acute renal failure of critical illness in Australia. Crit Care Med 2001;29:1910-5. PMID: 11588450 DOI: http://dx.doi.org/10.1097/00003246-200110000-00010
39. Thakar CV, Christianson A, Himmelfarb J, Leonard AC. Acute kidney injury episodes and chronic kidney disease risk in diabetes mellitus. Clin J Am Soc Nephrol 2011;6:2567-72. DOI: http://dx.doi.org/10.2215/CJN.01120211
40. Bhandari S, Turney JH. Survivors of acute renal failure who do not recover renal function. QJM 1996;89:415-21. DOI: http://dx.doi.org/10.1093/qjmed/89.6.415
41. Manhes G, Heng AE, Aublet-Cuvelier B, Gazuy N, Deteix P, Souweine B. Clinical features and outcome of chronic dialysis patients admitted to an intensive care unit. Nephrol Dial Transplant 2005;20:1127-33. DOI: http://dx.doi.org/10.1093/ndt/gfh762
42. Srisawat N, Murugan R, Lee M, Kong L, Carter M, Angus DC, et al.; Genetic and Inflammatory Markers of Sepsis (GenIMS) Study Investigators. Plasma neutrophil gelatinase-associated lipocalin predicts recovery from acute kidney injury following community-acquired pneumonia. Kidney Int 2011;80:545-52. PMID: 21677634 DOI: http://dx.doi.org/10.1038/ki.2011.160
43. Wald R, Quinn RR, Adhikari NK, Burns KE, Friedrich JO, Garg AX. et al.; University of Toronto Acute Kidney Injury Research Group. Risk of chronic dialysis and death following acute kidney injury. Am J Med 2012;125:585-93. PMID: 22516564 DOI: http://dx.doi.org/10.1016/j.amjmed.2012.01.016
44. Collins AJ, Foley RN, Herzog C, Chavers B, Gilbertson D, Ishani A, et al. US Renal Data System 2010 Annual Data Report. Am J Kidney Dis 2011;57:A8, e1-526. DOI: http://dx.doi.org/10.1053/j.ajkd.2009.10.009
45. Chawla LS, Amdur RL, Amodeo S, Kimmel PL, Palant CE. The severity of acute kidney injury predicts progression to chronic kidney disease. Kidney Int 2011;79:1361-9. PMID: 21430640 DOI: http://dx.doi.org/10.1038/ki.2011.42
46. Wald R, Quinn RR, Luo J, Li P, Scales DC, Mamdani MM. et al.; University of Toronto Acute Kidney Injury Research Group. Chronic dialysis and death among survivors of acute kidney injury requiring dialysis. JAMA 2009;302:1179-85. PMID: 19755696 DOI: http://dx.doi.org/10.1001/jama.2009.1322
47. Amdur RL, Chawla LS, Amodeo S, Kimmel PL, Palant CE. Outcomes following diagnosis of acute renal failure in U.S. veterans: focus on acute tubular necrosis. Kidney Int 2009;76:1089-97. PMID: 19741590 DOI: http://dx.doi.org/10.1038/ki.2009.332