Quality of Care for Acute Kidney Disease: Current Knowledge Gaps and Future Directions

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Abstract:

Acute Kidney Injury (AKI) and acute kidney disease (AKD) are common complications in hospitalized patients and are associated with adverse outcomes. While consensus guidelines have improved the care of patients with AKI and AKD, guidance around quality metrics in the care of patients following an episode of AKI/AKD is limited. For example, few patients receive follow-up laboratory testing of kidney function or post-AKI/AKD care through nephrology or other providers. Recently, the Acute Disease Quality Initiative (ADQI) developed a consensus statement regarding the quality improvement goals for patients with AKI/AKD specifically highlighting the efforts around quality and safety of care after hospital discharge following an episode of AKI/AKD. The goal is to use these measures to identify opportunities for improvement that will positively impact outcomes. We recommend that health care systems quantitate the proportion of patients who need and actually receive follow-up care following their index AKI/AKD hospitalization. The intensity and appropriateness of follow-up care should depend on patient characteristics, severity, duration, and course of AKI/AKD, and should evolve as evidence-based guidelines emerge. Quality indicators for discharged patients with dialysis requiring AKI/AKD should be distinct from ESRD measures. Besides, there should be specific quality indicators for those still requiring dialysis in the outpatient setting following AKI/AKD. Given the limited pre-existing data guiding the care of patients after an episode of AKI/AKD, there is ample opportunity to establish quality measures and potentially improve patient care and outcomes. This manuscript will provide specific evidence-based and expert-opinion-based guidance for the care of patients with AKI/AKD after hospital discharge.

Acute Kidney Injury (AKI) is a common clinical syndrome and remains associated with increased morbidity, mortality, and cost of care,[1,2] despite recent publications demonstrating that AKI rates and severity may be reduced through the use of care bundles.[3-5] The Kidney Disease Improving Global Outcomes (KDIGO) AKI workgroup originally introduced the concept of Acute Kidney Disease (AKD) to underscore the importance of prolonged kidney dysfunction (in the presence or absence of AKI) that may occur before a patient meets the 90-day criteria needed for the diagnostic criteria of chronic kidney disease (CKD).[6] Subsequently, the Acute Disease Quality Initiative (ADQI) proposed staging criteria for AKD (Figure 1).[7] Since the care of AKI is not well standardized, it should be of no surprise that the follow-up care of patients with AKD is even less so and no published quality and patient care guidelines exist. ADQI is a multi-professional, interdisciplinary consensus organization that identifies areas of importance within the field of AKI and develops consensus statements around clinical care and research. Recently, ADQI XXII met to develop quality improvement goals for AKI and AKD.[8] Here, we will discuss the opportunities to establish quality measures in those with AKI/AKD after hospital discharge.

Statement 1 – To optimize the care of patients with AKI/AKD, health care systems need to quantitate the proportion of patients who need and do receive follow-up care following their index AKI/AKD hospitalization.

Given the significant morbidity and mortality associated with AKI, a comprehensive medical follow-up is desirable, although the evidence base in terms of quality metrics is sparse.[9] Even in cases of severe AKI, patients rarely receive nephrology follow-up; in a retrospective cohort study of U.S. Veterans, only 17 of 57 subjects with Stage 3 AKI were referred for follow-up.[10] However, despite a lack of robust data to support their beliefs, most nephrologists and healthcare providers believe that follow up after an episode of AKI/AKD is important.[11] As a first step, healthcare systems need to systematically determine the proportion of hospitalized patients who have AKI/AKD as well as the number who receive post-discharge follow-up care. Once baseline numbers are established, they can then be followed as a

quality indicator. This will allow health care systems to identify barriers to appropriate follow-up and how best to achieve appropriate follow-up in 100% of patients.

As discussed below, the type and intensity of follow-up will depend on patient characteristics and the severity of AKI/AKD. Depending on local systems, it may be most practical to take a staged approach to quality improvement. This can be done through large scale data collection tools to look at system-wide practices, but it may be easiest to start tracking the follow-up for those patients seen by nephrology who received RRT during their admission; systems must find a model that works for them and build on it. Using quality improvement approaches, barriers to follow-up care should be identified and remediated. If the proportion of those receiving proper care is already high or as this proportion increases, subsequent quality improvement efforts can focus on less severe AKI/AKD populations. The Appendix provides a case-based example of how this process could work.

Statement 2: Intensity and appropriateness of follow-up depend on patient characteristics as well as severity, duration, and course of AKI.

Given the increasing numbers of patients with severe AKI/AKD and the workforce issues within nephrology, it is important to prioritize those patients most in need of nephrology follow-up. Even within the group of patients with the most severe AKI, follow up is suboptimal; in a cohort of patients with AKI following cardiac surgery, only 66 of 359 (18%) received nephrology follow up within the first postoperative year despite 54% of the cohort having received RRT in the early postoperative period.[12] The majority of this group should have ideally received follow-up in a nephrology-focused, multi-disciplinary setting, such as a dedicated post-AKI/AKD clinic, where the nephrologist can collaborate with allied health care practitioners (pharmacy, dietician, social work) and primary care. However, follow up for less severe AKI/AKD (e.g., Stage 1 AKI) may be through non-nephrology providers, including primary care and other medical subspecialists. We must acknowledge that while some areas or countries may be able to provide care to all AKD patients, in other areas or countries the number of AKI/AKD survivors may be greater than the capacity for the nephrology community to provide care. As

such, these non-nephrology providers play an integral role in the long-term care of post-AKI/AKD patients. Follow-up may be ensuring that full recovery has occurred based on lab testing (e.g., serum creatinine (SCr) and albuminuria) or monitoring for sequelae of AKI that may be associated with the development of CKD (e.g., hypertension, development of albuminuria).

Patient Characteristics:

The healthy patient with no comorbidities who suffers a short, transient and completely reversible episode of AKI does not require nephrology follow-up. When serum creatinine has returned to baseline at the time of discharge, then patient assessment at 6-12 months, perhaps as a part of routine care with a primary care provider including simple kidney blood and urine tests, would be reasonable. When individuals have a more protracted AKI/AKD course, follow up within 3-6 months seems appropriate. When there is stage 3 AKI/AKD with non-recovery, follow up should engage specialist services at appropriate times (see Figure 2), often within days of discharge. In addition to AKI/AKD severity, patient comorbidities are a key determinant for the type/intensity of follow-up. Patients with significant co-morbidities, in particular those with significant CKD, should remain under close nephrology care.

To determine which post-AKI/AKD patients were at the highest risk for the development of CKD, James and colleagues derived (Alberta) and validated (Ontario) a predictive model using data from over 12,500 Canadian admissions.[13] Their risk score is composed of 6 graded components, including patient age, gender, baseline Scr, degree of albuminuria, peak AKI stage, and discharge SCr. The most heavily weighted variable in the score is discharge SCr, with the most points being awarded for those who had a SCr > 1.3 mg/dL. While this score was externally validated in its original publication, it has yet to be validated in other international cohorts or implemented on a wide scale.[13]

While the James score provides some clues as to who needs closer follow up for long-term complications of AKI, it is important also to remember that those with recent AKI-related acute complications such as acid-base/electrolyte disorders, volume overload, and incomplete kidney recovery will also require close nephrology follow-up.

Indeed, patients with severe AKI appear to have better outcomes with specialist follow-up, although those already under nephrology care prior to AKI/AKD may fare less well, probably reflecting the complications of long-standing kidney disease.[14] Importantly, the absence of CKD does not imply that follow up is not needed. Readmission following AKI/AKD is common in patients with chronic obstructive pulmonary disease, urinary tract infection, and those with volume-overload/pulmonary edema.[15,16] Emerging data suggest that patients with documented AKI are at increased risk for heart failure re-admission. [17,18]

Timing of Follow Up

There is no evidence as to the optimal timing of follow-up after an episode of AKI. Figure 2 shows our proposed schema with regards to the timing of follow up. The recommended timing cannot be viewed in isolation but is tailored to the patient comorbidities and severity of AKI/AKD as well as the need for follow-up with nephrology or non-nephrology providers. As follow up becomes more standardized, it may be appropriate for health care systems to track AKI/AKD outcomes specifically at 90 days or perhaps at 1 year as well as ascertain who is providing that care.

Emerging data suggest that measuring urinary albumin to creatinine ratio (uACR) 3 months after hospital discharge following an episode of AKI may allow for the identification of patients at highest risk for kidney disease progression (defined as halving of eGFR or development of end-stage kidney disease (ESRD).[19] In a multi-center prospective observational cohort of 1,538 North Americans, uACR at three months was a valuable stratification tool for kidney disease progression, while severity/staging of AKI was not. In the future, measuring uACR post-AKI may be linked with specific protocolized interventions in high-risk patients.[19] Future investigations should attempt to discern the impact of early versus late follow-up as well as the ability of other biomarkers to stratify long term patient outcomes.

Potential Interventions

Similar to timing, AKI/AKD follow-up investigations depend on patient comorbidities and the severity of AKI/AKD. Given the relative lack of evidence-based care in this population, a standardized definition of "appropriate" follow-up care is needed. Nephrologists need to identify patients who benefit from follow-up the most. Based on the limited published evidence and current expert opinion, we recommend the following key components of a post-AKI/AKD bundle (Table 1).[8] Compliance with the whole bundle, or individual components, can then be used as a quality indicator over time. The "KAMPS" care bundle includes functional kidney testing, including both GFR estimation and indices of tubular and glomerular dysfunction (e.g., albuminuria/proteinuria). Blood pressure control, as well as review of medications, is paramount, particularly concerning over-the-counter and herbal therapies. Communication with other health providers and the patient are key, particularly in relation to medications that may need monitoring during episodes of acute illness (e.g., medications excreted predominantly by the kidney and nephrotoxic drugs, KENDS [kidney excreted nephrotoxic drugs]). Keeping a close eye on KENDS, medication review/reconciliation is an essential part of AKI/AKD care and should occur at the first post-discharge and all future clinic appointments.[20] While nephrologists are ideally equipped to do post-AKI/AKD medication review/reconciliation this can be done by pharmacists. While many of these components are not derived from multi-center studies, they are all grounded in the consensus care for patients with AKI.[6] Adherence to such an approach will potentially provide optimal management strategies and standardize care. Monitoring of adherence and subsequent clinical outcomes will lead to the development of a more robust evidence base for the care of these patients.

Improving care for AKD patients requires a change from the current management paradigm as well as prioritization and implementation efforts. Appropriate risk stratification, timely, reliable pharmacologic treatments, and education of patients, their caregivers, and non-nephrologists could be strategies to optimize care. The post-AKI/AKD care process starts as an inpatient at the time of hospital diagnosed AKI, continues in the community, and should even include any/all readmissions. Each of these phases requires specific interventions, with nephrologists leading the multi-disciplinary, AKI/AKD process.

To start, care should focus on the AKI to CKD transition, especially in regards to the high risk of subsequent ESRD and cardiovascular disease. Since only a minority of patients with severe AKI/AKD (e.g., Stage 2 or 3 AKI) actually receive dedicated nephrology follow-up, emphasizing the need for appropriate long-term nephrology care earlier in the inpatient stay should allow for more appropriate outpatient follow-up. In a retrospective propensity-score matched cohort study nephrology follow-up after AKI has been associated with lower all-cause mortality compared to non-nephrology care (hazard ratio 0.76 (95%CI 0.62 to 0.93).; however, the nature of this benefit needs to be investigated further, perhaps through randomized controlled trials as well as to determine the benefits of follow up in less severe forms of AKI.[14]

Statement 3 - Post AKI/AKD care should be evidence-based and evolve with emerging data.

Tertiary prevention involves managing a disease process after it is already clinically apparent. AKI increases the incidence of *de novo* CKD, 30-day readmission after discharge, long-term dialysis, remote organ injury, and death.[21-24] The tertiary prevention of AKI should focus on maintenance and/or improvement in the quality of life after AKI to mitigate any long-term comorbidities/ consequences.[25] However, as with other areas of post-AKI/AKD care, there is no high-level clinical evidence that current follow-up care plans impact these outcomes.

Rates of kidney-related laboratory testing after hospital discharge are low. In the United States in 2013, follow-up creatinine measurements after an episode of AKI occurred within six months in only 54% of surviving patients.[26] This data is even more concerning when one considers that following AKI/AKD, many fewer patients have quantitative proteinuria, parathyroid hormone, hemoglobin, and phosphorus measurements. While not all AKI/AKD patients may require each of these measurements, this retrospective data demonstrates that a minority of "appropriate" patients receive standard nephrology follow-up.[27]

Multiple AKI researchers have proposed that the transition period between AKI and CKD, may be an opportunity to intervene. However, currently, there are no proven interventions that enable long-

term target organ protection in AKD patients. Emerging animal models and limited retrospective human data suggest that interventions including improved blood pressure control, avoidance of nephrotoxins, and the initiation of renin-angiotensin-aldosterone system (RAAS) blockade agents[28,29] or mineralocorticoid receptor antagonists[30], may prevent the progression of kidney disease and its complications. However, in humans, following an episode of AKI administration of RAAS agents may increase the risk of hyperkalemia as well as the need for nephrology based hospitalization.[29]

In a retrospective cohort study of U.S. adults, post-AKI patients had a 22% increase in the odds of developing HTN.[31] However, RAAS agents are associated with functional AKI, especially in the setting of acute hypovolemia.[6,32,33] Following any hospitalization, patients are at risk for unintentional medication discontinuation, and hypertension agents are often discontinued during inpatient stays in the setting of hypotension/transfer to the ICU. As such, medication reconciliation is an essential part of post-AKI/AKD care. Potential discrepancies should be accounted for after hospital discharge to ensure they are meeting established targets recommended by hypertension, diabetes, lipid, and CKD practice guidelines.[34]

From a population-based cohort study, statin use is associated with reduced risks of 1-year and in-hospital mortality in patients with dialysis-requiring AKI (AKI-D)[35], and with decreased sepsis-related mortality in patients with advanced CKD.[36] Data from a retrospective cohort demonstrate that in diabetic patients with a history of AKI-D, dipeptidyl peptidase 4 inhibitors (DPP4i) use is associated with a reduced risk of ESRD and mortality.[37] Finally, clinically unwarranted receipt of medications which have been specifically implicated and associated with increased risk of AKI (e.g., proton-pump inhibitors or non-steroidal anti-inflammatory drugs) should be avoided.[38] While there is minimal prospective data to inform these recommendations, medication reconciliation, avoidance of potential nephrotoxins and appropriate medication dosing seem like proper steps in improving outcomes in patients following an episode of AKI/AKD

Statement 4: Quality indicators for AKI-D and post-discharge AKD-D should be similar to quality indicators during hospitalization, and distinct from ESRD measures. In addition, there need to be specific quality indicators for the outpatient setting. For example, compliance with the WATCH-ME care bundle could be considered.

In contrast to the ESRD population, there are currently no established quality indicators for AKI-D care.[39] A key limitation has been the lack of large-scale, prospective, clinical trials to support specific measures.[40] ESRD quality measures may not be appropriate for the AKI population, as patients with AKI will be at greater risk for complications and also have the additional goal of kidney function recovery. Determining factors that predict and promote kidney recovery following AKI-D may help to improve the quality of care. Premature designation of patients with AKI-D as ESRD may constitute a lost opportunity to promote kidney recovery.[41]

As patients with AKI-D transition from the acute period into the outpatient setting, it is critical for them to be recognized as a population with special needs. This begins with an appropriate handoff to the outpatient team and includes the education of providers and the patients themselves. Based on the available retrospective cohort data and expert opinion, we recently proposed key elements (the WATCH-ME care bundle, Table 2) for high-quality AKI-D care in the outpatient setting.[8]

Weight Assessment

In contrast to the paradigm of dry weight challenges for ESRD patients, AKI-D patients may require a mild "permissive hypervolemia" approach that emphasizes avoidance of intradialytic hypotension (IDH). The dangers of IDH and high ultrafiltration rates (>13 mL/kg/hr) in ESRD patients have been well-described[42]. In AKI-D, IDH may exacerbate ischemic kidney injury and decrease the chances of recovery.[43] Two separate retrospective studies found that higher ultrafiltration rates and more frequent IDH were associated with a lower likelihood of recovery in outpatients with AKI-D.[43,44] At a minimum, patients with AKI-D should have a regular (weekly) reassessment of target weight and fluid removal goals. In non-anuric patients, diuretics may be helpful to limit inter-dialytic weight gain and

decrease ultrafiltration rates.[45] The role of specific measures to prevent IDH, such as cooled dialysate or sodium modeling, has not been formally assessed in the AKI setting.

Access

Nearly all patients with AKI-D will have a central venous catheter (CVC) as primary access. Furthermore, placement of arteriovenous access should be delayed (appropriately) while monitoring for kidney function recovery.[46] These patients and their families will be at significant risk for infectious complications, and they should receive proper CVC care/education before hospital discharge, which should continue as an outpatient. While limited data around these CVC issues exist in those with AKI-D, much can be learned from investigations in other populations with CVCs. [47,48] Patients with AKI-D should receive training around vein preservation. Delivery of these educational components is an excellent example of an important and easy quality measure for health systems/dialysis facilities to track.

Teaching

By definition, AKI-D is a potentially reversible condition, and studies suggest that upwards of 40% of patients with AKI-D who are discharged on dialysis may recover to dialysis independence.[44,49,50] Patients and their caregivers need to be educated to monitor for kidney function recovery. Many patients with AKI-D will not have had the benefit of nephrology care before their acute illness, so broader education regarding kidney health should be included when appropriate.[14,46] In the dialysis facility, patients with AKI-D should be clearly identifiable separately from ESRD patients. AKI-D patients should undergo a regular care plan meeting (similar to the ESRD process) that articulates the individual's clinical trajectory and their personalized expectations for kidney recovery.

Clearance

We believe dialysis facilities caring for patients with AKI-D need to have the appropriate processes to allow for more frequent blood and urine testing, assessing for kidney recovery.[46] This can be

done through bloodwork (e.g., trending pre-dialysis serum creatinine) and/or timed urine collections, and should be pursued at least weekly during the outpatient transition.[51]

Dialysis clearance should also be measured and used to guide prescription. Evidence from the large-scale, randomized-controlled ATN trial suggests that for patients with AKI-D, a delivered Kt/V urea of 1.2 thrice weekly can be considered adequate dialytic clearance.[52] However, patients with AKI-D may have more individualized needs, such as higher catabolism requiring more dialysis for symptomatic control of uremia. Conversely, patients who begin to recover kidney function may tolerate a tapering of dialysis to less than three weekly treatments.

***H**ypotension*

IDH is associated with adverse outcomes and may decrease the likelihood of kidney function recovery in patients with AKI-D.[43,44] Emphasizing the importance of limiting inter-dialytic weight gain is essential, as is the careful adjustment of antihypertensive medications.

***ME**dications*

As with any transition in healthcare settings, the move to outpatient AKI-D management should be accompanied by review and reconciliation of medications.[53,54] The review and reconciliation process needs to be frequently repeated, especially when kidney function begins to recover, to ensure adequate/appropriate dosing of medications.[20] Patients should be educated on the potential impact of kidney failure and dialysis on drug clearances, but they should also be instructed that as kidney function begins to recover, drug clearances may be improved, and medication dosing may need to be increased or even discontinued. A specific review of common nephrotoxic medications and KENDS should also be performed.[20]

In addition to the above potential measures that focus on processes of care, ideally, outcomes measures such as hospital readmission rates and dialysis independence recovery rates should be monitored.

However, there are currently no established benchmarks, and these rates will vary based on patient characteristics. Given the dearth of data in this area, monitoring these rates can help to identify trends and potentially quality improvement opportunities.

Conclusions

Quality measures are needed for the management of AKI/AKD patients after the index hospitalization to standardize care and improve patient outcomes. Relatively few patients receive follow up laboratory testing of kidney function or post-AKI/AKD care. Table 3 provides a potential initial quality scorecard for a health care system to begin to monitor and improve their AKI/AKD care. While this tool has not been validated, it is based on the limited published data and expert opinion. It captures the basic numbers an institution will need to track in the short and long term to care for patients with AKI/AKD. Similarly, Appendix A provides a hypothetical quality improvement project related to the care of patients with AKI/AKD.

In the future, outcomes such as 30-day readmission rates, catheter-associated infection rates, and short- and long-term mortality following an episode of AKI/AKD may be quality metrics that will be reported. For now, healthcare institutions should be aware of the number of patients who warrant post-AKI/AKD care as well as track the numbers who go on to receive some form of follow up. This focused follow-up care could be provided by either nephrology and non-nephrology providers, and this may be an important metric to track. Future quality improvement work and research could focus on the optimal management strategies and clinical effectiveness of the KAMPS and WATCH ME bundle components and the potential development and validation of new bundles.

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Supplemental Material:

1) **Acknowledgments: The ADQI XXII participants**
2) **Appendix A:** Sample quality improvement project. A hypothetical quality improvement project related to the care of patients after AKI and during AKD.
3) Supplementary Figure 1: Pareto Chart for analysis of the lack of appropriate medication list review at discharge and communication with primary physicians.

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References:

1. Chertow GM, Burdick E, Honour M, Bonventre JV, Bates DW. Acute kidney injury, mortality, length of stay, and costs in hospitalized patients. *J Am Soc Nephrol.* 2005;16(11):3365-3370.
2. Hobson C, Ozrazgat-Baslanti T, Kuxhausen A, et al. Cost and Mortality Associated With Postoperative Acute Kidney Injury. *Annals of surgery.* 2015;261(6):1207-1214.
3. Meersch M, Schmidt C, Hoffmeier A, et al. Prevention of cardiac surgery-associated AKI by implementing the KDIGO guidelines in high risk patients identified by biomarkers: the PrevAKI randomized controlled trial. *Intensive Care Med.* 2017.
4. Gocze I, Jauch D, Gotz M, et al. Biomarker-guided Intervention to Prevent Acute Kidney Injury After Major Surgery: The Prospective Randomized BigpAK Study. *Annals of surgery.* 2018;267(6):1013-1020.
5. Selby NM, Casula A, Lamming L, et al. An Organizational-Level Program of Intervention for AKI: A Pragmatic Stepped Wedge Cluster Randomized Trial. *J Am Soc Nephrol.* 2019;30(3):505-515.
6. KDIGO. Kidney Disease: Improving Global Outcomes (KDIGO) Acute Kidney Injury Work Group. KDIGO Clinical Practice Guideline for Acute Kidney Injury. *Kidney Int.* 2012;Supp(2):1-138.
7. Chawla LS, Bellomo R, Bihorac A, et al. Acute kidney disease and renal recovery: consensus report of the Acute Disease Quality Initiative (ADQI) 16 Workgroup. *Nat Rev Nephrol.* 2017;13(4):241-257.
8. Kashani K, Rosner MH, Haase M, et al. Quality Improvement Goals for Acute Kidney Injury. *Clin J Am Soc Nephrol.* 2019;14(6):941-953.
9. Sawhney S, Marks A, Fluck N, et al. Post-discharge kidney function is associated with subsequent ten-year renal progression risk among survivors of acute kidney injury. *Kidney Int.* 2017;92(2):440-452.
10. Siew ED, Peterson JF, Eden SK, et al. Outpatient nephrology referral rates after acute kidney injury. *J Am Soc Nephrol.* 2012;23(2):305-312.
11. Karsanji DJ, Pannu N, Manns BJ, et al. Disparity between Nephrologists' Opinions and Contemporary Practices for Community Follow-Up after AKI Hospitalization. *Clin J Am Soc Nephrol.* 2017;12(11):1753-1761.
12. Mishra PK, Luckraz H, Nandi J, et al. Long-term quality of life postacute kidney injury in cardiac surgery patients. *Annals of cardiac anaesthesia.* 2018;21(1):41-45.
13. James MT, Pannu N, Hemmelgarn BR, et al. Derivation and External Validation of Prediction Models for Advanced Chronic Kidney Disease Following Acute Kidney Injury. *Jama.* 2017;318(18):1787-1797.
14. Harel Z, Wald R, Bargman JM, et al. Nephrologist follow-up improves all-cause mortality of severe acute kidney injury survivors. *Kidney Int.* 2013;83(5):901-908.
15. Sawhney S, Marks A, Fluck N, McLernon DJ, Prescott GJ, Black C. Acute kidney injury as an independent risk factor for unplanned 90-day hospital readmissions. *BMC Nephrol.* 2017;18(1):9.
16. Silver SA, Harel Z, McArthur E, et al. 30-Day Readmissions After an Acute Kidney Injury Hospitalization. *Am J Med.* 2017;130(2):163-172.e164.
17. Lee BJ, Hsu CY, Parikh RV, et al. Non-recovery from dialysis-requiring acute kidney injury and short-term mortality and cardiovascular risk: a cohort study. *BMC Nephrol.* 2018;19(1):134.
18. Bansal N, Matheny ME, Greevy RA, Jr., et al. Acute Kidney Injury and Risk of Incident Heart Failure Among US Veterans. *Am J Kidney Dis.* 2017.
19. Hsu CY, Chinchilli VM, Coca S, et al. Post-Acute Kidney Injury Proteinuria and Subsequent Kidney Disease Progression: The Assessment, Serial Evaluation, and Subsequent Sequelae in Acute Kidney Injury (ASSESS-AKI) Study. *JAMA Intern Med.* 2020.

20. Ostermann M, Chawla LS, Forni LG, et al. Drug management in acute kidney disease - Report of the Acute Disease Quality Initiative XVI meeting. *Br J Clin Pharmacol.* 2018;84(2):396-403.
21. Wu VC, Wu CH, Huang TM, et al. Long-term risk of coronary events after AKI. *J Am Soc Nephrol.* 2014;25(3):595-605.
22. Wu VC, Yang SY, Lin JW, et al. Kidney impairment in primary aldosteronism. *Clin Chim Acta.* 2011;412(15-16):1319-1325.
23. Lai CF, Wu VC, Huang TM, et al. Kidney function decline after a non-dialysis-requiring acute kidney injury is associated with higher long-term mortality in critically ill survivors. *Crit Care.* 2012;16(4):R123.
24. Wu VC, Shiao CC, Chang CH, et al. Long-term outcomes after dialysis-requiring acute kidney injury. *BioMed research international.* 2014;2014:365186.
25. Shiao CC, Wu PC, Huang TM, et al. Long-term remote organ consequences following acute kidney injury. *Crit Care.* 2015;19:438.
26. USRDS. https://www.usrds.org/2016/view/v1_05.aspx]. USRDS. Published Chapter 5 - Acute Kidney Injury Accessed April 15,2019, 2019.
27. Matheny ME, Peterson JF, Eden SK, et al. Laboratory test surveillance following acute kidney injury. *PloS one.* 2014;9(8):e103746.
28. Cheng SY, Chou YH, Liao FL, et al. Losartan reduces ensuing chronic kidney disease and mortality after acute kidney injury. *Scientific reports.* 2016;6:34265.
29. Brar S, Ye F, James MT, Hemmelgarn B, Klarenbach S, Pannu N. Association of Angiotensin-Converting Enzyme Inhibitor or Angiotensin Receptor Blocker Use With Outcomes After Acute Kidney Injury. *JAMA Intern Med.* 2018;178(12):1681-1690.
30. Lin YF, Chen L, Lin SL, et al. Potential target-organ protection of mineralocorticoid receptor antagonist in acute kidney disease. *J Hypertens.* 2019;37(1):125-134.
31. Hsu CY, Hsu RK, Yang J, Ordonez JD, Zheng S, Go AS. Elevated BP after AKI. *J Am Soc Nephrol.* 2016;27(3):914-923.
32. Ftouh S, Thomas M. Acute kidney injury: summary of NICE guidance. *BMJ (Clinical research ed).* 2013;347:f4930.
33. Lapi F, Azoulay L, Yin H, Nessim SJ, Suissa S. Concurrent use of diuretics, angiotensin converting enzyme inhibitors, and angiotensin receptor blockers with non-steroidal anti-inflammatory drugs and risk of acute kidney injury: nested case-control study. *BMJ (Clinical research ed).* 2013;346:e8525.
34. Silver SA, Goldstein SL, Harel Z, et al. Ambulatory care after acute kidney injury: an opportunity to improve patient outcomes. *Canadian journal of kidney health and disease.* 2015;2:36.
35. Wu CL, Kor CT, Chang CC, Chiu PF, Tarng DC, Hsu CC. Association of Statin Use With Mortality After Dialysis-Requiring Acute Kidney Injury: A Population-Based Cohort Study. *Mayo Clinic proceedings.* 2018;93(10):1474-1483.
36. Huang TM, Wu VC, Lin YF, et al. Effects of Statin Use in Advanced Chronic Kidney Disease Patients. *Journal of clinical medicine.* 2018;7(9).
37. Chen CY, Wu VC, Lin CJ, et al. Improvement in Mortality and End-Stage Renal Disease in Patients With Type 2 Diabetes After Acute Kidney Injury Who Are Prescribed Dipeptidyl Peptidase-4 Inhibitors. *Mayo Clinic proceedings.* 2018;93(12):1760-1774.
38. Tsai IJ, Lai TS, Shiao CC, et al. Proton-Pump Inhibitors Augment the Risk of Major Adverse Cardiovascular Events and End-Stage Renal Disease in Patients with Acute Kidney Injury After Temporary Dialysis. *Clinical pharmacology and therapeutics.* 2020.
39. Mehboob A, Zimmerman R, Abramson S, Parker MG. Quality measures in acute kidney injury. *Current opinion in nephrology and hypertension.* 2018;27(2):130-135.

40. Rewa O, Mottes T, Bagshaw SM. Quality measures for acute kidney injury and continuous renal replacement therapy. *Curr Opin Crit Care.* 2015;21(6):490-499.
41. Heung M, Faubel S, Watnick S, et al. Outpatient Dialysis for Patients with AKI: A Policy Approach to Improving Care. *Clin J Am Soc Nephrol.* 2015;10(10):1868-1874.
42. Chou JA, Kalantar-Zadeh K, Mathew AT. A brief review of intradialytic hypotension with a focus on survival. *Semin Dial.* 2017;30(6):473-480.
43. McAdams M, Ortiz-Soriano V, Jordan M, et al. Kidney recovery in patients discharged to an acute rehabilitation facility with acute kidney injury requiring hemodialysis . *Clin Nephrol.* 2019;92(1):15-24.
44. Pajewski R, Gipson P, Heung M. Predictors of post-hospitalization recovery of renal function among patients with acute kidney injury requiring dialysis. *Hemodial Int.* 2018;22(1):66-73.
45. Sibbel S, Walker AG, Colson C, Tentori F, Brunelli SM, Flythe J. Association of Continuation of Loop Diuretics at Hemodialysis Initiation with Clinical Outcomes. *Clin J Am Soc Nephrol.* 2019;14(1):95-102.
46. Cerdá J, Liu KD, Cruz DN, et al. Promoting Kidney Function Recovery in Patients with AKI Requiring RRT. *Clin J Am Soc Nephrol.* 2015;10(10):1859-1867.
47. Tan SH, Lee KC, Chao YF, Hsu LF, Lin PC. Effects of a family involvement program in patients with central-line insertion. *Clin Nurs Res.* 2015;24(3):253-268.
48. DeLa Cruz RF, Caillouet B, Guerrero SS. Strategic patient education program to prevent catheter-related bloodstream infection. *Clin J Oncol Nurs.* 2012;16(1):E12-17.
49. Hickson LJ, Chaudhary S, Williams AW, et al. Predictors of outpatient kidney function recovery among patients who initiate hemodialysis in the hospital. *Am J Kidney Dis.* 2015;65(4):592-602.
50. Gautam SC, Brooks CH, Balogun RA, Xin W, Ma JZ, Abdel-Rahman EM. Predictors and Outcomes of Post-Hospitalization Dialysis Dependent Acute Kidney Injury. *Nephron.* 2015;131(3):185-190.
51. Milutinovic J, Cutler RE, Hoover P, Meijsen B, Scribner BH. Measurement of residual glomerular filtration rate in the patient receiving repetitive hemodialysis. *Kidney Int.* 1975;8(3):185-190.
52. Network VNARFT, Palevsky PM, Zhang JH, et al. Intensity of renal support in critically ill patients with acute kidney injury. *N Engl J Med.* 2008;359(1):7-20.
53. Coleman EA, Smith JD, Raha D, Min SJ. Posthospital medication discrepancies: prevalence and contributing factors. *Arch Intern Med.* 2005;165(16):1842-1847.
54. Tam VC, Knowles SR, Cornish PL, Fine N, Marchesano R, Etchells EE. Frequency, type and clinical importance of medication history errors at admission to hospital: a systematic review. *Cmaj.* 2005;173(5):510-515.

Figure 1 - **The spectrum of acute kidney injury (AKI), acute kidney disease (AKD), and chronic kidney disease (CKD).** AKI, AKD CKD can form a spectrum of diagnoses where AKI can whereby initial kidney injury can potentially lead to the development of CKD. AKD describes a process of damage and/or loss of kidney function for a duration of between 7 and 90 days after exposure to an AKI initiating event. For patients with pre-existing CKD, the AKI event can be superimposed on CKD, with AKD existing on a background of CKD. Patients who suffer AKD with pre-existing CKD are probably at high risk of kidney disease progression. Modified from ADQI XVI; www.adqi.org. [7]

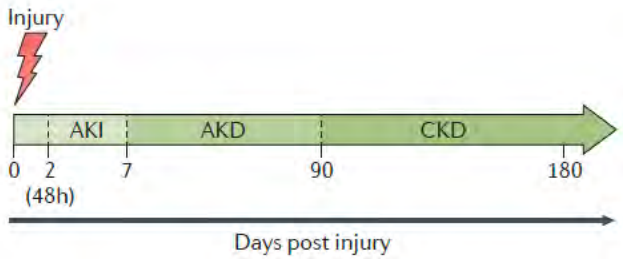

Figure 2 – Schematic for AKI/AKD follow-up.

The figure displays a paradigm for the care of patients who experience AKI/ AKD. Follow up with nephrology and non-nephrology change based on the duration and severity of AKI/AKD and vary along the horizontal axis. The timing and nature of follow up are suggestions as there is limited data to inform this process. Acute Disease Quality Initiative XXII; www.adqi.org. [8]

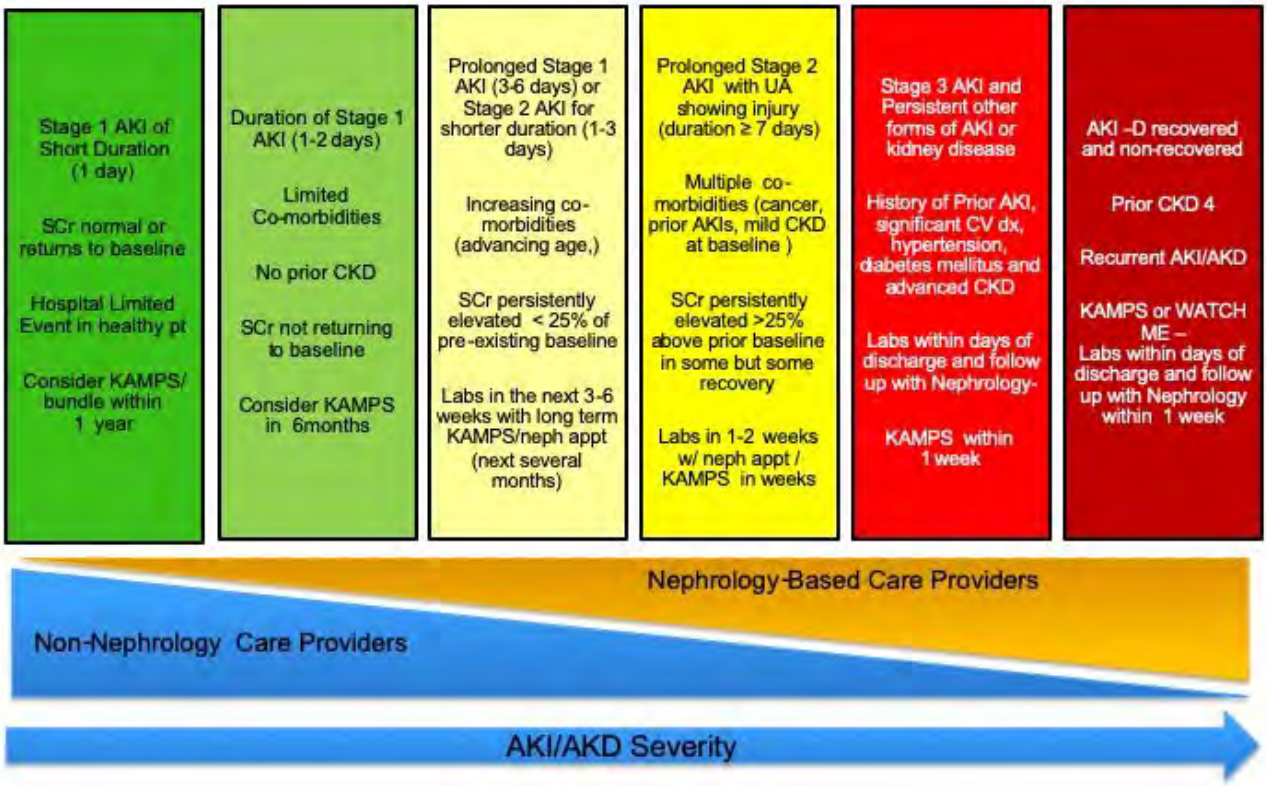

Figure 2

Table 1 Post AKI/AKD Kidney Health Care Bundle

KAMPS	**Components**
Kidney Function Check	• Kidney function measurement by serum creatinine or cystatin C; measured or estimated GFR • Proteinuria / albuminuria • When available consider biomarkers, imaging and other tests as feasible and indicated
Advocacy	• Patient and Caregiver education about AKI and CKD • Communication with other care providers (i.e., general practitioners, dieticians, nurses, pharmacists, and social workers)
Medications	• Medication reconciliation, review, and management • Specifically, discuss the risk benefits of ACEI/ARB • Review KENDs and over the counter medications
Pressure	• Ensure patient understands blood pressure goals and targets • Discuss fluid status, ideal weight and the role of diuretics
Sick Day Protocols	• Educate patients on medications that need monitoring during acute illnesses • Consider protocols to withhold KENDs

KENDS- Kidney l Excreted and Nephrotoxic Drugs

ACEI- Angiotensin Converting Enzymes Inhibitors

ARB- Angiotensin Receptor Blockers

Table 2 : AKI-D/ AKD-D Kidney Health Care Bundle

WATCH-ME	Components
Weight Assessment	• Discuss Dry Weight monitoring and permissive hypervolemia • Discuss the role of diuretics in maintaining urine output and ideal volume status
Access	• Educate patients about the care of central venous catheters • Vein preservation protocols / awareness • When appropriate begin to plan and educate about the role of arteriovenous access and other RRT modalities
Teaching	• Patient and Caregiver education about dialysis requiring AKD and short- and long-term risks and consequence • Communication with other care providers (e.g., general practitioners, dieticians, nurses, pharmacists, and social workers) about patient needs (e.g., alterations in medication regimens in the setting of new RRT).
Clearance	• Frequent assessments of underlying kidney function (via pre-dialysis labs or timed clearances) • Frequent assessments of the quality of the RRT being provided to ensure adequate clearance
Hypotension	• Patient Education and optimization of care to avoid intradialytic about hypotension • Education around blood pressure medications administration in the peri-RRT period
MEdications	• Medication reconciliation, review, and management • Specifically, discuss the risk benefits of ACEI/ARB • Review KENDs and over the counter medications

Abbreviations: AKI-D, acute kidney injury requiring dialysis; AKD-D, acute kidney disease requiring dialysis; AKD, acute kidney disease; RRT, renal replacement therapy; ACEI, angiotensin-converting enzyme inhibitor; ARB, angiotensin receptor blocker; KENDs, Kidney excreted and Nephrotoxic drugs

Table 3: Potential Quality Score Card to Track The Follow-up Care of Patients with AKI/AKD

	Current Quarter's Numbers /Rate	Prior Quarter's Numbers / Rate	Prior Year's Event Rate	Current Year's Goal Rate
Patients with Dialysis-Requiring AKI/AKD				
Of those with Dialysis-Requiring AKI/AKD Number of Unique Hospitalized Patients				
Of those with Dialysis-Requiring AKI/AKD Number of patients Surviving to Hospital Discharge				
Number of patients having a measure of kidney function (SCr, Cystatin C, proteinuria, etc.) within 30 days of discharge				
Number of patients who no longer need RRT 90 days post-discharge				
Number of patients who no longer need RRT by 90 days post-discharge who received nephrology follow up within 6 months				