Nephrology Training: Time to Revisit Integrative Physiology

Shweta Bansal^{a, c} Rushit Kanakia^b Kumar Sharma^{a, c} Steve Tsai^{b, c}
Anand Prasad^b

^aDivision of Nephrology, University of Texas Health at San Antonio, San Antonio, TX, USA; ^bDivision of Cardiology, University of Texas Health at San Antonio, San Antonio, TX, USA; ^cSouth Texas Veterans Healthcare System, San Antonio, TX, USA

Background

Close relationship between heart and kidneys has existed since the evolution of human kind and the term “cardiorenal syndrome” was adopted in early 2000s to better understand this interaction to improve the prognosis of patients with cardiorenal disorders. The classification of cardiorenal syndrome into five subtypes was the initial step to simplify the concept; however, the interplay between the kidneys and the cardiovascular system is very complex involving hemodynamics (fluids, pressures, flows, resistances, perfusion), chemical (electrolytes, pH, and toxins), and biological (inflammation, immune system activation, neurohormonal signals) processes. Cardiovascular disease (CVD) is a major cause of morbidity and mortality in patients with acute kidney failure, chronic kidney disease (CKD), on maintenance dialysis and after kidney transplantation [1]. Moreover, the presence of kidney disease introduces a significant layer of complexity in the management of patients with CVD. For example, atrial fibrillation (AF) patients with CKD are at heightened risk of ischemic stroke as well as bleeding with anticoagulants; frequent fluid/electrolyte shifts in dialysis patients can precipitate sudden arrhythmic death in patients with CVD [2, 3]. With respect to prevention, the accepted class of statin drugs, most widely employed for primary and secondary prevention for

CVD in multiple populations, has been shown to be futile in dialysis patients [4]. These management challenges are expected to become more urgent in the coming decades as the US population ages, a greater number of individuals suffer from diabetes, hypertension, and obesity leading to a rising prevalence of CKD. CKD now involves 14.6% of the United States adult population according to latest 2018 Annual Data Report of the United States Renal Data System as compared to 10% of the population in 1988–1994 [1]. With an increasing prevalence of CKD, the number of patients with ESRD is also multiplying, 726,331 US adults had ESRD in 2018 as compared to 484,995 prevalent cases in 2005. As stated above, CVD prevalence remains all-time high in the patients with CKD and is the major cause of mortality and morbidity. In 2018, 64.5% of patients older than 66 years with CKD had CVD, compared to 32.4% of non-CKD population. Over a 2-year period, Medicare patients with both heart failure and CKD had an adjusted survival probability of 77.8%, compared to 90.2% for those with CKD alone. AF was common among Medicare patients with CKD (23.8%). Nearly half of CKD patients with heart failure had a diagnosis of AF. Furthermore, the presence of CKD is associated with worsened short- and long-term prognosis for many common CVDs, for example, the adjusted 2-year survival of patients with acute myocardial infarction was 59% for CKD stage 4–5 patients as compared to

82% without CKD [1]. In brief, these complex interactions have grown at epidemic proportion and require extra skills in managing cardiorenal disorders.

Loss of Integrative Physiology

Although all organ systems in the body function in an integrated fashion, the advanced training in medicine in current era has been branched into organ-specific subspecialties, that is, cardiology, nephrology, hepatology, endocrinology, and so on. In the zeal of focused subspecialization while managing patients, more than often we lose the application of integrative physiology of these organ systems which is the integration of mechanisms and regulatory functions at all biological levels from the molecular, cellular to tissue level. Understanding of the interaction between organ systems is very essential particularly for renal disorders since kidneys are central in the integrative physiology of different organ systems with examples such as cardiorenal, hepatorenal, oncorenal, ICU-nephrology disorders. Thus, the management of cardiorenal disorders requires knowledge and recognition of the complex interactions between heart and kidneys. For example, when a hospitalized patient with congestive heart failure and volume overload does not respond to loop diuretics, the management requires the understanding of right and down shift of diuretics dose – response curve in CKD and heart failure patients, instead of invasive ultrafiltration for volume removal. Similarly, when serum creatinine rises during the process of diuresis despite no other nephrotoxic insult, it is important to understand the high pressure/volume load in heart and need for further diuresis rather than volume administration to improve the patients' overall outcome. The cross-training among these specialties is key forward step to treat the complex patients. However, in the current system, we have lost the integrative physiology training.

Current Trends in Nephrology Training

Despite the growing prevalence of CKD and associated CVD, mortality, and morbidity, and thus increasing need for nephrologists, the interest in nephrology subspecialty training has been declining. Over last few years, approximately 40% of the nephrology fellowship positions and 60% of the nephrology training tracks have been unfilled through National Resident Matching Program [5]. Sev-

eral factors have contributed to this phenomenon, and one of the major factors has been the growing perception among internal medicine trainees that the breadth of clinical practice in nephrology is shrinking, as several areas traditionally within the scope of nephrology move into the realm of specialties such as critical care, interventional radiology, and hospitalist medicine [6], which is in a way a reflection of comprehending the need of integration of multiorgan physiology as in many circumstances kidney injury is the bystander to the dysfunction of the other organ systems with its own consequences. To address this concern, joint subspecialties have emerged within the field of nephrology such as critical care nephrology, onco-nephrology, and nephro-hospitalist [7–9]. These are the perfect setups of cross training in integrated systems required for the finest management of complex patients.

As outlined above, cardiorenal medicine is an additional area of high demand for cross training given the increasing prevalence of these complex disorders. “Calls to action” have been initiated to stimulate universities, medical schools, and teaching hospitals to create a core curriculum for cardiorenal medicine to better equip the physicians of the future for these common, serious, and frequently fatal syndromes [10, 11].

Innovative Cardiorenal Track

In response to this call-to-action, at University of Texas Health at San Antonio, we have created an innovative cardiorenal training track with in the nephrology fellowship as a concerted effort between the Divisions of Nephrology and Cardiology to bridge the gaps in knowledge and skills in cardiorenal medicine and to serve as stimulus to rekindle the interest in nephrology. The goal of the track is to foster the development of a “nephrocardiologist” who is competent managing complex cardiorenal interactions and is a critical member of the multidisciplinary patient care team. Table 1 outlines the learning objectives to meet this goal. Each of the leaning objectives relies on the awareness and knowledge of integrated pathophysiology of heart and kidneys.

Curriculum

The Nephrology fellowship at UT Health San Antonio is designed to provide an outstanding clinical and academic training experience. Over the 2-year of general ne-

Table 1. Learning objectives of cardiorenal track

Focus area
<p><i>Pathogenesis</i></p> <p>a. Explain the role of metabolic diseases as the underlying cause of CVD and CKD</p> <p>b. Illustrate and describe the pathogenesis of volume overload, cardiorenal syndromes, and diuretic resistance in heart failure including HErEF, HEpEF, and right-sided heart failure</p>
<p><i>Prevention</i></p> <p>a. Summarize primary and secondary prevention of renal and CVD in patients with at risk for either disease or presence of at least one disease</p> <p>b. Demonstrate the need and methods to optimize renal outcomes during acute cardiac events such as heart failure exacerbation or acute coronary syndromes and cardiovascular procedures such as angiography and cardiothoracic surgery</p>
<p><i>Diagnosis</i></p> <p>a. Review basic electrocardiographic monitoring, interpreting output from device interrogation, and being efficient in decisions to reduce the risks of sudden death</p> <p>b. Review indications and analyze basic interpretation of noninvasive cardiovascular imaging such as transthoracic echocardiography, stress testing, vascular testing, and coronary angiography</p> <p>c. Formulate and develop volume status assessment using adjunct bedside tools such as point-of-care ultrasound scans</p> <p>d. Demonstrate understanding of the indications and cardiac-risk stratification for pre-renal transplant patients</p> <p>e. Exhibit understanding of preoperative cardiology clearance procedures in advanced CKD</p>
<p><i>Treatment</i></p> <p>a. Review new emerging novel therapies for heart failure and the cardiorenal syndromes</p> <p>b. Manage novel anticoagulation to prevent stroke and systemic embolism in patients with AF and ventricular thrombi with CKD</p> <p>c. Manage patients with acute coronary syndromes in patients with advanced CKD</p> <p>d. Formulate a plan during acute cardiac events and cardiovascular procedures with insight to improve renal outcomes</p>
<p><i>Innovation/research</i></p> <p>a. Aim to learn more about why patients with primarily cardiovascular or kidney disease develop dysfunction of other organ system</p> <p>b. Improve diagnostic strategies in cardiorenal syndromes utilizing biomarkers, imaging modalities, and volume status determination</p> <p>c. Undertake and participate in ongoing multicenter collaborative studies and clinical trials in cardiorenal medicine to improve outcomes for patients with kidney and CVD</p>
<p>CVD, cardiovascular disease; CKD, chronic kidney disease; HErEF, heart failure with reduced ejection fraction; HEpEF, heart failure with preserved ejection fraction; AF, atrial fibrillation.</p>

phrology, fellows rotate in three large hospitals (University Hospital, VA Medical Center and San Antonio Military Medical Center), transplant service, and 5-star rated outpatient dialysis units. Additionally, multiple electives and track opportunities are available to foster a broad clinical exposure tailored to the interest of the fellow. Fellows interested in research are given four months of protected time with an optional third year. In the cardiorenal track (identified at the time of interviews), fellows rotate through multiple cardiology disciplines during their elective and research months (Table 2). In this track, fellows have option to choose from one of the two pathways:

A. Clinical pathway: provides a multidisciplinary clinical experience in prevention and management of patients with kidney and heart disease in both inpatient and outpatient settings.

B. Academic pathway: fosters career focus in translational and clinical research in cardiorenal medicine.

During the cardiology rotations, the focus is on managing patients with coexisting heart and kidney diseases and preventing new development of kidney diseases following the above learning objectives. Both cardiology and nephrology faculty supervise the fellows to improve the understanding of cardiorenal interactions and generate healthy discussions to integrate the care based on the best available evidence. Few examples include managing hospitalized patient with heart failure exacerbation (which could be heart failure with reduced ejection fraction or heart failure with preserved ejection fraction or right sided heart failure [12]) and loop-diuretic resistance; CKD stage IV patient requiring cardiac catheterization/contrast for unstable angina, and so on. The fel-

Table 2. Nephrology rotation schedule for cardiorenal track

<i>Year-1</i>	
6 Months of general nephrology	
University hospital acute consult (2 months)	
VA hospital acute consult (2 months)	
Transplant service – inpatient and outpatient (1–2 months)	
SA military center hospital acute consult (1–2 months)	
6 Months of cardiorenal rotations	
Academic pathway	
1-month CCU	
1-month noninvasive imaging/heart station	
4 months of research in cardiorenal arena	
Clinical pathway	
1-month CCU	
1-month noninvasive imaging/heart station	
1-month of catheterization lab	
1-month cardiology consult service	
1-month of heart failure program	
1-month of electrophysiology rotation	
Formal didactics	
Cardiorenal experts	
Clinical pharmacologist	
12 Months of half-day per week nephrology continuity clinic	
<i>Year-2</i>	
9 Months of general nephrology	
University hospital acute consult (3 months)	
VA hospital acute consult (2–3 months)	
Transplant service – inpatient and outpatient (1–2 months)	
SA military center hospital acute consult (1–2 months)	
2 Months of outpatient renal replacement therapy rotation	
Hemodialysis clinic	
Peritoneal dialysis clinic	
Transplant clinic	
1 Month of elective	
Heart failure program or	
Catheterization lab or	
Interventional nephrology or	
Critical care	
12 Months of half-day per week nephrology continuity clinic	
<i>Year-3 (optional)</i>	
12 Months of research in cardiorenal area	
One half-day clinic in cardiology and nephrology continuity clinics	
CCU, cardiology care unit.	

low attends once a week innovative cardiorenal clinic initiated by cardiorenal experts, Drs. Anand Prasad and Shweta Bansal [13, 14] at Medical Arts and Research Center of UT health San Antonio to provide comprehensive care to the patients with co-existent CVD and kidney disease. Moreover, these fellows participates in the planning and execution of an annual 2-day continuing educational course held at UT Health San Antonio “Cardio-Renal Connections Meeting” under the guidance of

course directors Drs. Anand Prasad and Shweta Bansal (www.cardiorenalconnections.org). Additional didactics are arranged for these fellows to focus on cardiorenal topics.

To continue to meet ACGME requirements for the Nephrology fellowship, throughout the 2 years of fellowship including cardiology elective months, the fellow (a) attends a half-day nephrology continuity clinic; (b) attends regular nephrology conferences including cardiorenal conference series provided by both nephrologists and cardiologists; (c) contributes to the weeknight and weekends calls, and jeopardy system similar to other nephrology fellows. We are hosting our first 2 cardiorenal track fellows starting July 2019.

Expected Outcomes from Cardiorenal Track

At the completion of the 2-year nephrology fellowship with cardiorenal track, the graduate will be American Board of Internal Medicine (ABIM) – Nephrology board eligible. In terms of future prospective, the graduate will be very competitive for any regular nephrology positions with a niche in managing patients with cardiorenal disorders, the prevalence of which is growing rapidly with epidemic of obesity and diabetes. Given the increasing buying of individual group-practices by hospitals, these graduates with cardiorenal expertise will especially be attractive for hospital-based practices with their own cardiovascular centers. The interested fellow may also be a more competitive applicant for future CVDs fellowship positions. Most of the cardiology rotations within the proposed construct are offered during first year, so that the interested candidates can apply to the match for CVDs fellowships during their second year.

Evaluation Tools

In order to improve design and implementation, this newly created program will be evaluated periodically, and activities will be adapted to ensure they are as effective as they can be. Initially, four main outcomes will be monitored: (a) fellows feedback, (b) impact on in-training exam and ABIM main exam scores, (c) medical knowledge, and (d) future career pathways. The learner will rank (0–5 scale) the following aspects at the end of each cardiorenal rotation: learning objectives of the particular rotation, process of implementation, instruc-

tor's effectiveness, integration with cardiology learners, and overall satisfaction. During the cardiology electives, cardiorenal fellows' skill development will be continuously tracked for six competencies in medical education including medical knowledge and patient care. In addition, they will be required to complete a 20-questions pre- and post-rotation questionnaires to assess the knowledge development during each elective rotation.

Future Directions

As the more cardiovascular centers are founded requiring cardiorenal expertise and the future of nephrology becomes clearer, our training structure will need to adjust. American Society of Nephrology has convened an ambitious project to assess the future of nephrology and how training should be adapted to fulfill these needs. ABIM has indicated a willingness to work with American Society of Nephrology to revise trainee requirements, and ACGME is open to creative training approaches. One of the approaches, we propose, is to create a combined 6-year internal medicine, nephrology, and cardiology program devoting 24, 18, and 30 months, respectively. This track can satisfactorily fulfill all the current ACGME requirements for these three disciplines. The proposed track will provide a good background data regarding the feasibility of this approach.

Conclusions

The cardiorenal track is an initial attempt to address the need for cardiorenal expertise by reintroducing integrative physiology and thus rekindling the interest in nephrology. The divisions of Nephrology and Cardiology in the Department of Medicine at UT health San Antonio provide the platform for this innovative track given their coexistent collaboration with the availability of combined cardiorenal clinic, continuing education activities in cardiorenal field, and dedicated and motivated faculty.

Acknowledgments

The authors are immensely thankful to our cardiology and nephrology colleagues who are aware of the need of the time, showed great interest, and supported the development of this track. They also want to show their gratitude to Dr. William L. Henrich (nephrologist), President of UT Health San Antonio, Dr. Brian Reeves (nephrologist), Chair of Department of Medicine and Dr. Scott Jones, Dean of Graduate Medical Education for their insight, support, and resources.

Disclosure Statement

Authors declare no conflict of interest in regard to this work.

Funding Source

This work received no specific funding from any agency.

References

- 1 United States Renal Data System 2018 Annual Report. [Accessed on May 2, 2019]. Available from: <https://www.usrds.org>.
- 2 Garlo KG, Steele DJ, Nigwekar SU, Chan KE. Demystifying the Benefits and Harms of Anticoagulation for Atrial Fibrillation in Chronic Kidney Disease. *Clin J Am Soc Nephrol*. 2019 Jan;14(1):125–36.
- 3 Green D, Roberts PR, New DI, Kalra PA. Sudden cardiac death in hemodialysis patients: an in-depth review. *Am J Kidney Dis*. 2011 Jun; 57(6):921–9.
- 4 Palmer SC, Navaneethan SD, Craig JC, Johnson DW, Perkovic V, Nigwekar SU, et al. HMG CoA reductase inhibitors (statins) for dialysis patients. *Cochrane Database Syst Rev*. 2013 Sep;(9):CD004289.
- 5 The National Resident Match Program Result Statistics for Medical Specialties. [Accessed May 2, 2019]. <http://www.nrmp.org/fellowships/medical-specialties-matching-program/>.
- 6 Nair D, Pivert KA, Baudy A 4th, Thakar CV. Perceptions of nephrology among medical students and internal medicine residents: a national survey among institutions with nephrology exposure. *BMC Nephrol*. 2019 Apr; 20(1):146.
- 7 Palevsky PM, Weisbord SD. Critical care nephrology: it's not just acute kidney injury. *J Am Soc Nephrol*. 2009 Nov;20(11):2281–2.
- 8 Yau TT, Humphreys BD. Role of the Nephro-Hospitalist. *Clin J Am Soc Nephrol*. 2019 Sep; 14(9):1405–7.
- 9 Abudayyeh AA, Lahoti A, Salahudeen AK. Onconeurology: the need and the emergence of a subspecialty in nephrology. *Kidney Int*. 2014 May;85(5):1002–4.
- 10 Rangaswami J, Mathew RO, McCullough PA. Resuscitation for the specialty of nephrology: is cardioneurology the answer? *Kidney Int*. 2018 Jan;93(1):25–6.
- 11 Ronco C, Ronco F, McCullough PA. A Call to Action to Develop Integrated Curricula in Cardiorenal Medicine. *Rev Cardiovasc Med*. 2017;18(3):93–9.
- 12 Bansal S, Prasad A, Linas S. Right Heart Failure—Unrecognized Cause of Cardiorenal Syndrome. *J Am Soc Nephrol*. 2018 Jul;29(7):1795–8.
- 13 Bansal S, Munoz K, Brune S, Bailey S, Prasad A, Velagapudi C. High-Dose Spironolactone When Patients With Acute Decompensated Heart Failure Are Resistant to Loop Diuretics: A Pilot Study. *Ann Intern Med*. 2019 Jul;171(6):443.
- 14 Prasad A, Garcia M. The Relationship of Dialysis Risk and Transcatheter Aortic Valve Replacement From the UK TAVI Registry: Study Findings: Some Expected, Some Provocative. *JACC Cardiovasc Interv*. 2017 Oct; 10(20):2048–9.