Learning Package

Health
Hunter New England
Local Health District
NSW GOVERNMENT

Renal: Anatomy, Physiology & Pathophysiology of the Renal System

Sites the learning package applies	Clinical areas where care is provided to patients with kidney disease require dialysis
Description	This learning package provides an overview of the basics of anatomy, physiology & pathophysiology of the renal system.
Target audience	Enrolled Nurses & Registered Nurses beginning to work in the area of nephrology nursing.
Learning Outcomes: **On completion of this package you will be better able to:**	• Identify the anatomical structures evident within the renal system. • Identify the functions of the kidney • Describe the process of urine formation • Relate the functions of the kidney to the pathophysiological processes occurring during urine formation. • Relate the knowledge of anatomy & physiology to the pathophysiology of kidney disease. • Differentiate acute injury & chronic disease.
Keywords	Anatomy, Physiology, Pathophysiology, Renal System, Acute Kidney Injury, Chronic Kidney Disease
Document registration number	17:03
Replaces existing document?	Yes
My Health Learning code	Renal: Anatomy, Physiology & Pathophysiology of the Renal System (168552289)
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Issue date	2018
Review date	2021

Renal: Anatomy, Physiology & Pathophysiology of the Renal System

Learning Package
2018

Learning Package Overview

Purpose: This package is designed to provide baseline information and to guide staff through the resources on anatomy, physiology and pathophysiology of the renal system. It will be useful for both Enrolled Nurses and Registered Nurses beginning to work in the area of nephrology nursing as well as those who would like to revise their knowledge on the subject.

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Date: 30/11/2017

Acknowledgements: this learning package is an adaptation of original work by:
- Sally Milson-Hawke, Anatomy & Physiology Self –Directed Learning Package
- Revised & updated 2008 by Karen Cairney Post Graduate Course 2008 Specialty Nursing A – Nephrology (in partnership with the University of Newcastle)
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Introduction
This learning package is one of a suite of packages aimed at offering guided learning for nephrology nurses to further enhance their clinical skills and knowledge. Baseline theoretical knowledge of anatomy, physiology and pathophysiology of the renal system that underpins the practice of nurses caring for patients with kidney disease is explored. The complexity of kidney disease requires nurses to understand how the kidneys normally function to understand the dysfunctional renal system.

Disclaimer
This learning package has been prepared by health professionals employed in Hunter New England Local Health District in the renal services. While all care has been taken to ensure that the information is accurate at the time of development, the authors recommend that all information is thoroughly checked before use if utilised by another unit, context or organisation.

Naming Convention
Renal: Anatomy, Physiology & Pathophysiology of the Renal System

Aim
To provide baseline theoretical knowledge of anatomy, physiology & pathophysiology of the renal system that underpins the practice of nurses caring for patients with kidney disease.

Learning Outcomes or Learning Objectives
Completion of this learning package will enable the learner to:
- *Identify the anatomical structures evident within the renal system.*
- *Identify the functions of the kidneys.*
- *Describe the process of urine formation.*
- *Relate the functions of the kidney to the pathophysiological processes occurring during urine formation.*
- *Relate the knowledge of anatomy and physiology to the pathophysiology of kidney failure.*
- *Differentiate acute kidney injury and chronic kidney disease.*

Pre-requisites
There are no formal prior learning requirements needed to undertake this learning package. This is entry level information for staff beginning to work in the area of nephrology nursing. For those people with a NSW Health employee number successful completion and submission of the learning package will be documented on My Health Learning.

Learning Package Outline
The package is a self-directed learning experience that will guide you through the literature and clinical issues related to anatomy, physiology & pathophysiology of the renal system. Completion of this package is equivalent to 6 (CPD) hours. Evidence of CPD can be generated using the reflection on learning.

Problem based learning

This program is based on a problem-based approach to learning. This approach has been chosen to enhance critical thinking, and to create a body of knowledge that the learner can apply to practice.

The package is developed with an adult learning framework so not all activities need to be documented but it is expected that you will complete them to facilitate your learning.

Instructions for participants

- It is estimated it will take an average of 4 hours to complete this package.
- Completion of this package is equivalent to Continuing Professional Development (CPD) hours which is a requirement for National Registration. Evidence of CPD can be generated using the reflection on learning page at the end of the package.
- Self-directed learning will be required to complete this package. Some activities will include essential reading and others will have additional supplementary readings that participants can undertake to further consolidate their knowledge.
- A brief outline of the topic followed by recommended readings & learning activities that will reinforce key points guide participants study.
- There is a suggested reference list but it is by no means complete. Please read widely to facilitate your learning. Journal articles can be accessed through CIAP. The online readings are not provided within this document due to copyright law restrictions. If you have any difficulty locating the readings please seek assistance from your relevant NE/CNE/CNS/CNC or hospital library.

<u>This SDLP uses the following icons:</u>

	READING **This icon alerts you to undertake reading related to the topic this may include Guidelines and Procedures, Journal Articles or Books**

	LEARNING ACTIVITY **This icon denotes a learning activity that you will need to complete**

	GUIDELINES **This icon alerts you to the presence of a guideline related to the subject**

Assessment process

When completed, you can return the package to relevant NE/CNE/CNS/CNC who will discuss the answers with you, provide constructive feedback. Successful completion of the package will be entered on My Health Learning.

Reflection tool

At the completion of the Learning Package we have added a reflection form that will assist staff in reflecting on the package and how it meets their professional development needs.

Evaluation

A form is included at the end of the learning package for completion by the learner. All feedback is appreciated and assists in development of a quality program. Please return the completed evaluation to your relevant NE/CNE/CNC.

Renal Anatomy

- *Ability to identify the anatomical structures evident within the renal system*

A sound knowledge of anatomy and physiology of the renal system underpins the practice of nurses caring for patients with kidney disease. The complexity of kidney disease requires that nurses understand how the kidneys normally function to understand the dysfunctional renal system.

The functional anatomy of the renal system includes the two kidneys, two ureters, a bladder and urethra (Lough, 2018). The kidney is the primary organ of interest in nephrology nursing practice.

LEARNING ACTIVITY

1. Familiarise yourself with the following diagrams that depict the anatomy of the renal system. When you feel you are familiar with these diagrams test your knowledge by trying to draw the diagrams from memory. Label your drawings with adrenal gland; urethra; ureter; bladder; kidney; cortex; medulla; capsule; renal column; renal pyramid; papilla; major calyx; minor calyx and renal pelvis. How did you go?

Sourced from:https://scioly.org/wiki/images

Sourced from: https://scioly.org/wiki/images
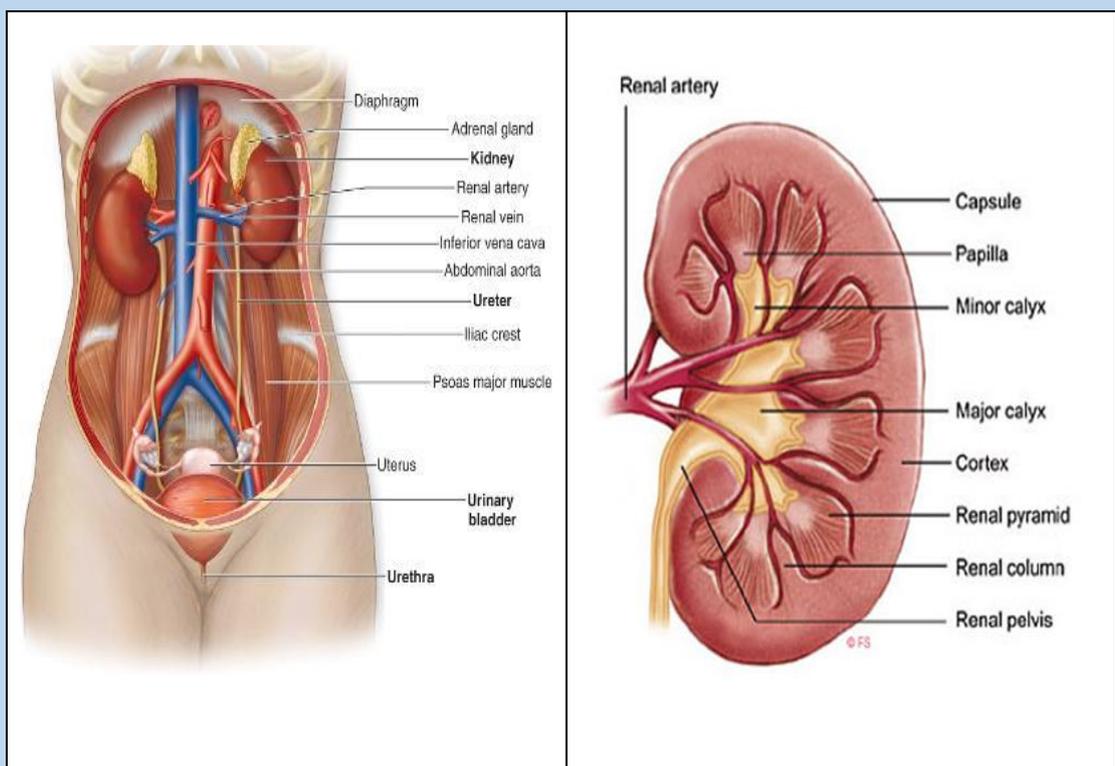
Macroscopic Anatomy of the Kidney

Cortex: This is the outer part of the kidney and it contains the glomeruli, proximal tubules, cortical portions of the loops of Henle, distal tubules, and cortical collecting ducts.

Medulla: This is the inner part of the kidney and it contains pyramids, medullary portions of the loops of Henle, the vasa recta, and the medullary portions of the collecting ducts.

Calyx: several minor calyces form a major calyx and the major calyces form the ureter, which transports urine to the bladder. Calyces are branches of the renal pelvis. The purpose of calyx is to collect urine and channel it down to the pelvis. From here it is transported using peristalsis to the ureter, which empties into the bladder (Lough, 2018)

Microscopic Anatomy of the Kidney

Each kidney has approximately 1.2 million nephrons. Nephrons are the functional unit of the kidney; they are the microscopic structures that produce urine (Hryciw, 2015)

- 80-85% cortical nephrons – which are located in the cortex and extend partially into the medulla, and have shorter loops of Henle
- 15-20% juxtamedullary nephrons – which lie close to and extend deep into the medulla, they have longer loops of Henle. It is the long loops of Henle that enable concentration of urine (Thomas, 2014)

Each nephron consists of vascular and tubular components (Kallenbach, 2016, p30)

Vascular component
The kidneys are highly vascular with about twenty percent of cardiac output going directly to the kidneys (Lough, 2018)

Afferent arteriole- Afferent means carrying towards; these are the arterioles that carry blood into the glomerular capillaries, where filtration occurs (Hryciw, 2015).

Glomerulus- is a network of blood capillaries where a positive filtration pressure exists. The difference in size of the afferent and efferent arterioles contributes to the high pressure that exists in the glomerulus which results in waste being filtered through the glomerular capillary walls. The three layers of the glomerulus include the endothelium, basement membrane and epithelium layers (Lough, 2018).

Efferent arteriole- Efferent means carry away, Glomerular capillaries reunite to form the efferent arteriole, which branches into the Peritubular capillaries and vasa recta capillaries, this is unique as this is the only time that arterioles both feed and drain a

capillary (Hryciw, 2015). Vasa recta have a major role in regulating the concentration of urine as it moves through the tubules (Kallenbach, 2016).

A The location and B components of the nephron
Sourced from (Hryciw, D. 2015, p. 822) https://www.clinicalkey.com.au/nursing/
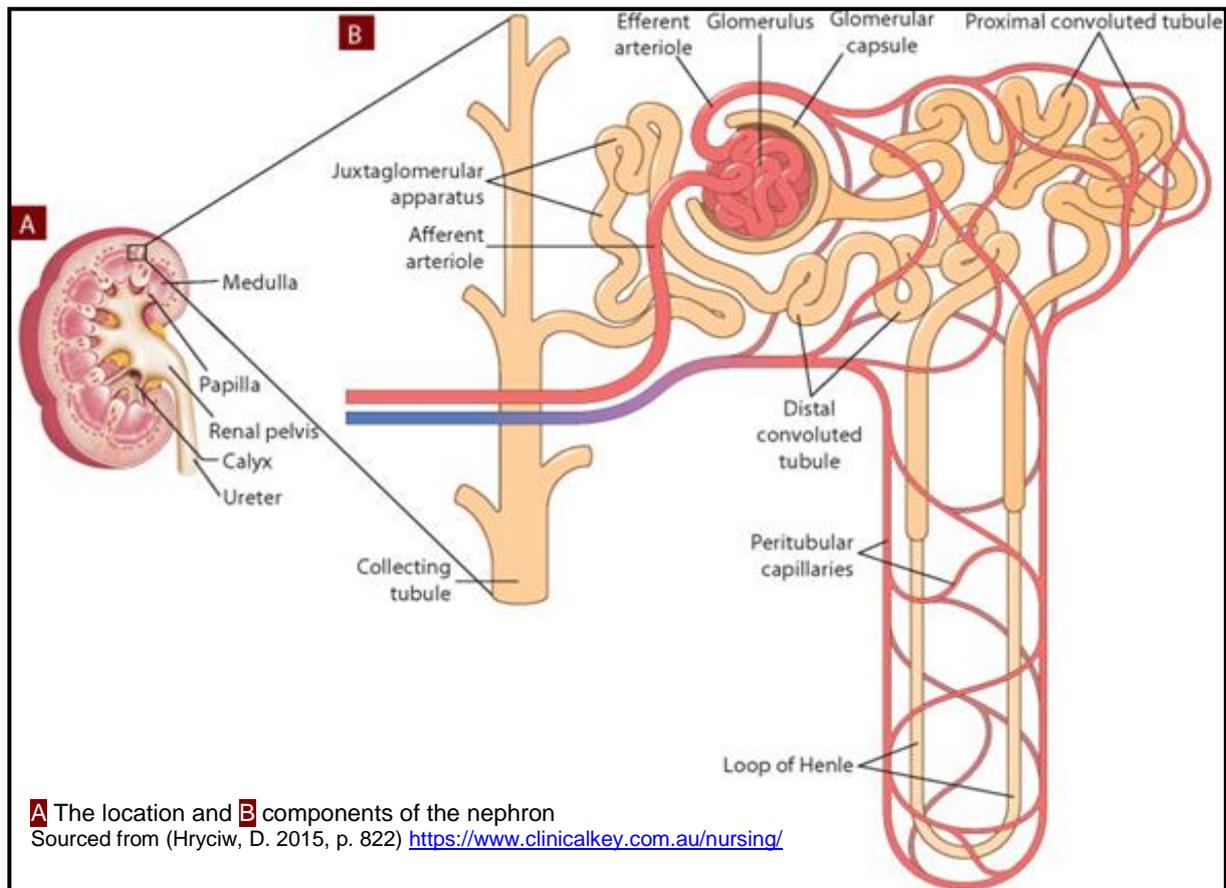
Tubular component (Lough, 2018)

- Bowman's capsule: surrounds the glomerulus, site of glomerular filtration.

- Proximal tubule: reabsorbs most of the filtered fluid and many of the solutes.

- Descending and ascending loop of Henle: can be differentiated between cortical nephron and juxtamedullary nephron. It plays a major role in urine concentration and dilution.

- Distal tubule-mainly reabsorbs solutes not water, which often leaves the tubule fluid hypo osmotic.

- Collecting duct- all around the collecting duct, the urine concentration is further influenced by antidiuretic hormone (ADH) to maintain haemostasis.

R	**READING** 1. Visit http://advancedrenaleducation.com/elearning/general-topics The Kidneys in Health and Disease module and complete the Renal Anatomy section. If this link ceases to work source this resource on the internet at advancedrenaleducation.com/

LEARNING ACTIVITY

2. List and define the functional units of the Kidney?

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3. Name the 2 arterioles that enter and leave the glomerular capillaries and state what their difference in size contributes to.

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Renal Physiology

- *Ability to identify the functions of the kidney*
- *Ability to describe the process of urine formation*
- *Ability to relate the functions of the kidney to the pathophysiological processes occurring during urine formation*
- *Ability to relate renal function abnormality to renal disease*

The functions of the kidney include the maintenance of a homeostatic environment. This is achieved by excretion of some of the waste products of metabolism which includes urea, creatinine, and uric acid and by adjusting the urinary excretion of water and electrolytes. The kidney is able to regulate individually the excretion of water and solutes such as sodium, potassium, and hydrogen, largely by changes in tubular reabsorption or secretion (Inker & Perrone, 2017).

The kidneys also have metabolic functions; these include the production of renin which helps regulate blood pressure, synthesis of erythropoietin which stimulates the production of red blood cells and conversion of vitamin D to its active form (Norton, Newman, Romancito, Mahooty, Kuracina & Narva, 2017).

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<table>
<tr><td>R</td><td>

READING

2. Visit http://advancedrenaleducation.com/elearning/general-topics and complete the Renal Physiology section in the eLearning course - The Kidneys in health and Disease. If this link ceases to work source this resource on the internet advancedrenaleducation.com/

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</table>

Urine formation

Three processes are involved in urine formation. Glomerular filtration, tubular reabsorption and tubular secretion (Kallenbach, 2016)

Glomerular filtration

This is the first constant process and involves water and solutes being forced through the glomerular capsule membrane into the renal tubal. (Marieb, 2014)

The normal glomerular filtration rate (GFR) is around 125ml/min, which indicates that there are approximately180 litres of fluid processed through the kidneys in 24 hours (Patton & Thibodeau 2018). In a healthy adult, the average urine output is around 1.5-2 litres, therefore the kidneys not only need to control the quality of filtration, but also manage reabsorption to maintain body euvolemic status.

Tubular reabsorption

This involves water, glucose, amino acids and required ions being transported out of the filtrate and into the blood capillaries (Marieb, 2014). The body's requirements at the time influence this process which is very selective (Kallenbach, 2016).

Tubular secretion,

This involves hydrogen ions, potassium ions and drugs being removed from the peritubular blood into the tubules (Marieb, 2014).

<table>
<tr><td>R</td><td>

READING

3. Hryciw, D. (2015) the Structure and function of the urinary system. In Craft, J., Understanding Pathophysiology – ANZ adaptation (pp. 820-842) Source this resource at https://www.clinicalkey.com.au/nursing/

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</table>

LEARNING ACTIVITY

3. The ability of a substance to be filtered through glomerular capillaries will depends on what two qualities?

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4. Define "glomerular filtration rate" and the average GFR level.

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5. Identify 4 pressures in the body that influence glomerular filtration rate and what factors may influence these pressures.

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6. Describe the process of how the macula densa and the afferent and efferent arteriole regulate the pressure of the glomeruli when the patient is experiencing a decrease in perfusion such as dehydration?

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Renin-Angiotensin System

The renin-angiotensin system is an important process in body fluid homeostasis and blood pressure regulation (Patton & Thibodeau 2018)
The following diagram describes this process.

Sourced from https://opentextbc.ca/anatomyandphysiology/chapter/25-4-microscopic-anatomy-of-the-kidney/
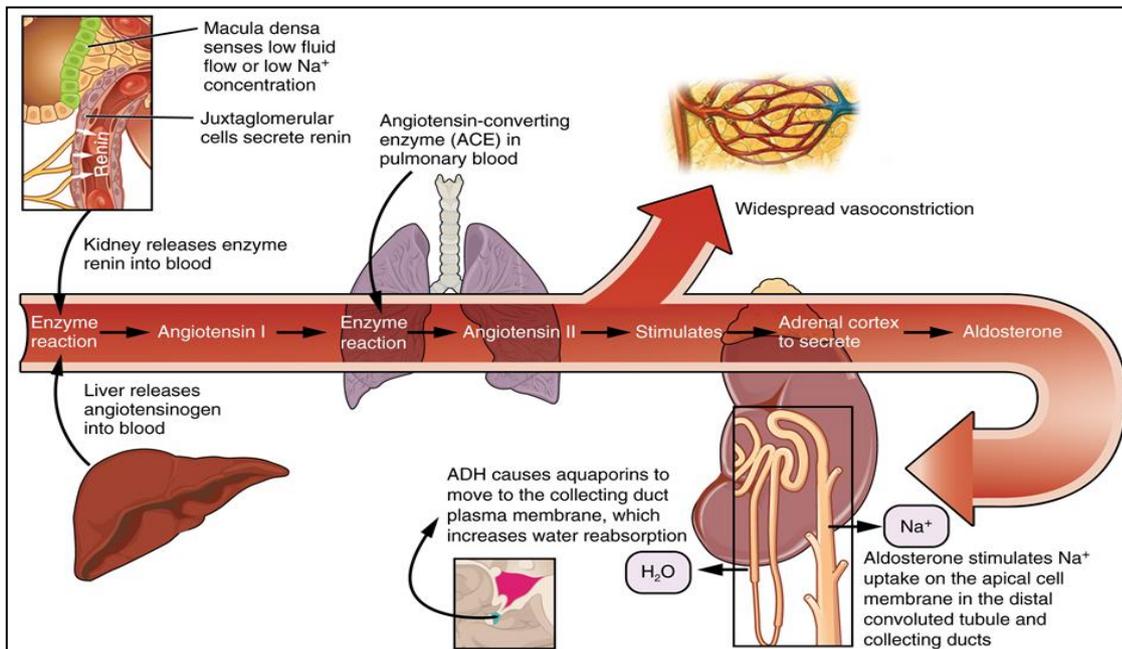
Synthesis of Erythropoietin

In response to a reduction in oxygen in the body the kidneys release erythropoietin into the blood stream. This stimulates the production of red blood cells in the bone marrow. The additional red blood cells raise the ability of the blood to absorb and transport oxygen (Patton & Thibodeau 2018)

Vitamin D Activation

The kidneys convert vitamin D from food sources and sun exposure into an active form for use by the body. Vitamin D affects bone and mineral metabolism (Hryciw 2015)

	READING
R	4. Norton, J.M., Newman, E.P. Romancito, G., Mahooty, S. Kuracina, T. & Narva, A.S. (2017). Improving Outcomes for patients with Chronic Kidney Disease: Part 1, American Journal of Nursing, 117 (2), 22-32
	5. Norton, J.M., Newman, E.P. Romancito, G., Mahooty, S. Kuracina, T. & Narva, A.S. (2017). Improving Outcomes for patients with Chronic Kidney Disease: Part 2, American Journal of Nursing, 117 (3), 26-35

LEARNING ACTIVITY

7. Identify the major functions of the kidney.

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8. According to identified functions of the kidneys, please list common complications that you may see in patients with chronic kidney disease.

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9. Angiotensin-converting enzyme (ACE) inhibitors and angiotensin receptor blockers (ARBs) are commonly prescribed medication for renal patients; please outline in short answers how these medications affect kidney functions?

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Acid-base Balance

Acid-base balance (pH) is necessary for normal physiology and cell metabolism and function. (Hamm, Nakhoul & Hering-Smith, 2015). Three systems contribute to acid base homeostasis, physiological buffers, the lungs and the kidneys. Buffers in the blood provide instant balancing of changes in pH. The lungs then compensate for changes in pH by increasing or decreasing carbon dioxide by changing ventilation. The kidneys have the main, longer lasting roll in acid base balance. The distal tubule of the kidney regulates acid–base balance by secreting hydrogen into the urine and reabsorbing bicarbonate. (Hryciw & Bonner, 2015) 70-80% percent of this filtered bicarbonate is reabsorbed in the proximal tubule; the rest is reabsorbed along more distal segments of the nephron. (Hamm et al, 2015)

LEARNING ACTIVITY

The following review questions draw on information presented throughout this learning package.

10. What are the 3 major components that regulate and maintain the body's pH level?

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11. How do the kidneys regulate acid base balance?

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12. What is the common symptom of a CKD patient when the buffering system is imbalanced due to impaired nephron function?

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13. What are some consequences of chronic metabolic acidosis?

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Pathophysiology of Acute Kidney Injury

- *Ability to define Acute Kidney Injury (AKI)*
- *ability to identify risk factors for AKI*
- *Ability to describe the causes of AKI*

Acute kidney injury (AKI) refers to a sudden decrease in kidney function which meets any of the following; an increase in serum creatinine by 0.3 mg/dL or more within 48 hours, an increase in serum creatinine to 1.5 times or more the baseline value within the prior 7 days or a decrease in urine output to less than 0.5 mL/kg/hour for 6 hours. Staging for the severity can be understood through the Kidney Disease: Improving Global Outcomes (KDIGO) definition and staging system which is the most recent and preferred staging system (Palevsky, 2017) The KDIGO staging system can be found in the next essential reading. There are many factors that can cause AKI and it is often classified as pre-renal, intra-renal or post-renal depending on the area of injury.

Sourced from http://med.wikidot.com
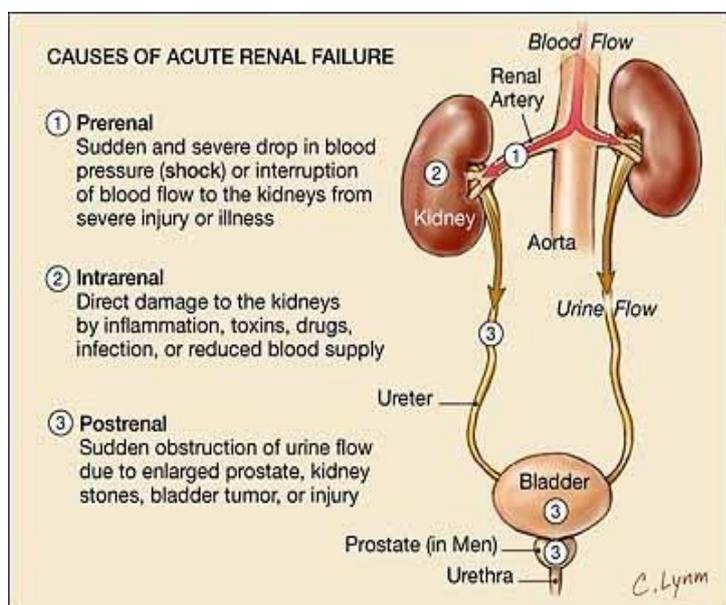
The damage associated with AKI is most often reversible and there are usually distinct phases to its clinical course, oliguric, diuretic, and recovery phase. However, in some cases AKI may not have an oliguric phase (Thornburg & Gray-Vickrey, 2016). Each phase has different clinical presentations; nurses need to have good understanding of the care for each different phase to assist patients to regain their kidney function.

	GUIDELINES
	Visit *http://www.cari.org.au/* and explore the guidelines on Acute Kidney Injury

	READING
	6. Thornburg, B. & Grey-Vickrey, P. (2016) Acute kidney injury; Limiting the damage Nursing 2016; 46(6):24-34

LEARNING ACTIVITY

14. List 6 risk factors for AKI.

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15. Outline the 3 major causes of AKI and state at least 2 clinical presentations that are associated with each cause.

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16. Outline some ways nurses can minimise AKI?

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Pathophysiology of Chronic Kidney Disease

- *Ability to define Chronic Kidney Disease (CKD)*
- *Ability to identify who is at risk of CKD*
- *Ability to outline common complications of CKD*

According to the major function of the kidneys discussed earlier in the package, it is not hard to understand what the clinical manifestations of chronic kidney disease (CKD) might be. As a renal nurse, it is not only important to recognise the common complications of CKD and its treatment, but more importantly to be able to understand risk factors for CKD and initiate prevention strategies to maintain quality of life for affected people.

READING

As you read through this document think about how CKD is defined, who is at increased risk of developing CKD and the complications that are associated with it and their management.

7.   Kidney Health Australia publication Chronic Kidney Disease (CKD) Management in General Practice, 3rd edition. Kidney Health Australia: Melbourne, 2015 access at http://kidney.org.au or via CIAP

8.   Smith, C.A. (2016). Evidence-based treatment of chronic kidney disease, Nurse Practitioner. 41(11) 42-48

LEARNING ACTIVITY

17. Provide a definition for CKD

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18. Identify the common risk factors for CKD.

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19. Identify 4 common complications of CKD, the common medications used for their management and describe the actions of the medication you have identified

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20. List the 4 options for treating ESKD?

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References

American Nephrology Nurses 'Association (Ed.). (2008). *Core Curriculum for Nephrology Nursing* (5th Ed). New Jersey, US: Anthony J. Jannetti, Inc**.**

Kidney Health Australia. (2015). Chronic Kidney Disease (CKD) *Management in General Practice, 3rd edition.* Retrieved from http://Kidney.org.au/

Hryciw, D. (2015). *the Structure and function of the urinary system.* In Craft, J., *Understanding Pathophysiology – ANZ adaptation* (pp. 820-842). Retrieved from *https://www.clinicalkey.com.au/nursing*

Hamm, L., Nakhoul, N. & Herring-Smith, K.S (2015). *Acid-base homeostasis*, Clin J AM Soc Nephrol 10 (12), 2232-2242

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Kallenbach, J.Z. (2016). *Review of hemodialysis for nurses and dialysis personnel. 9th edition.* Missouri: Mosby.

Lough, M.E. (2018) Kidney anatomy and physiology. In Urden, L.D. & Stacy, K.M, *Critical Care Nursing.* Retrieved from *https://www.clinicalkey.com.au/nursing*

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Norton, J.M., Newman, E.P. Romancito, G., Mahooty, S. Kuracina, T. & Narva, A.S. (2017). Improving outcomes for patients with chronic kidney disease: Part 2, American Journal of Nursing, 117 (3), 26-35

Patton, K.T. & Thibodeau, G.A. (2018) *The human body in health & disease (7th edition)* St, Louis, Missouri: Elsevier

Palevsky, P.M. (2017, April).*definition and staging of acute kidney injury.* Retrieved from https://www.uptodate.com

Smith, C.A. (2016). *Evidence-based treatment of chronic kidney disease.* Nurse Practitioner. 41(11) 42-48

Thornburg, B. & Grey-Vickrey, P. (2016). *Acute kidney injury: Limiting the damage*, Nursing 2016; 46(6):24-34

Learning Package: Reflection on Learning

This document guides your reflection on the extent to which the package meets your professional development needs, and how you plan to apply your learning into practice. This tool is not part of the assessment process, and has been included as a document that you may wish to include in your professional portfolio. Time taken to complete learning package_____

What was your purpose in completing this learning package?

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Did you achieve this by completing the learning package?

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Reflecting on the content, what key learning have you obtained?

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What learning will you apply to your practice immediately? How will you do this?

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What learning needs have you identified as a result of completing this learning package?

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How do you plan to address these needs?

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Signature:_____ Date:_____

Learning Package Evaluation Form

Your feedback regarding this learning package is important to ensure the package meets your learning needs. Please take 5 minutes to answer the following questions to facilitate any change required for future learning packages.

1. The learning outcomes of the learning package were clearly identified   Yes   No

2. The learning outcomes of the package were appropriate

3. The content provided enabled me to meet the learning outcomes?   Yes   No

4.The activities motivated my interest in the topic   Yes   No

5.The activities and workbook questions supported my understanding of the topic

6.The package was presented in a logical manner   Yes   No

7.The assessment process related to this package was clearly outlined (if applicable)   Yes   No

8. My most relevant learning outcomes from this package were:

_____
_____

9. The key learning points from this package I can immediately apply to practice include:

_____
_____

10. The least relevant component(s) of this package were:

_____
_____

11 Some suggestions I would like made to improve the package would be:

_____
_____

12. Further comments:

_____
_____

Thank you for your time to complete the evaluation
Please return to:

The relevant CNE/NE/CNC/NP within your area