EXPLORING THE ANATOMY AND PHYSIOLOGY OF AGEING

PART 4 – THE RENAL SYSTEM

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The fourth in this series on the effects of ageing explores the changes that occur within the renal system. This is the most powerful regulator of the body’s internal environment. Healthy kidneys are essential to maintain homeostasis, ensuring stable conditions in which all cells can function optimally. The kidneys perform multiple functions including (Montague et al, 2005):

- Removal of waste products such as urea, uric acid, creatinine and toxic breakdown products of drugs;
- Regulation of blood volume/pressure;
- Electrolyte (salt) balance;
- Acid-base balance (regulation of blood pH);
- Regulation of erythrocyte (red blood cell) numbers;
- Synthesis of vitamin D.

In the absence of disease, the kidneys will continue to function optimally well into the third decade of life, after which there is a gradual decline (Figs 1 and 2).

ANATOMICAL CHANGES

Pre-renal changes

The most important pre-renal (before the kidney) change to affect kidney function is vascular degeneration.

In young adults, renal blood flow has been estimated to be approximately 600ml/minute; in older people the flow is often reduced by half (Cukuranovic and Vlajkovic, 2005). This is primarily due to normal age-related changes within blood vessels (see part 1 in this series) and is often exacerbated in people with atherosclerosis of the renal artery.

Such vessel changes usually lead to ischaemia (reduced oxygenation), particularly within the outer portion of the kidney (renal cortex). Cells gradually begin to die and are replaced with scar tissue. This often gives the outer surface of aged kidneys a granular or mottled appearance.

Reduced blood flow has a dramatic effect on the glomerular filtration rate (GFR). The GFR of people in their 80s may be only 60–70% of that in healthy young adults. This reduces the clearance of waste products, potentially damaging health, particularly if associated pathologies are present.

Renal changes

Both the mass and weight of kidneys gradually decrease with age. The kidneys of young adults in their 20s typically weigh 250–270g; in a 90-year-old this will have dropped to 180–200g. It has been estimated that between the ages of 40 and 80 approximately 20% of kidney mass is lost (Choudhury et al, 2004).

By the age of 90, only 3% of people will have histologically normal kidney tissue. There is a gradual age-related increase in collagen deposition, leading to progressive kidney fibrosis. In old age whole nephrons are replaced by scar tissue (hylinisation) – on average, 70-year-olds have lost 30–50% of their original nephrons.

Aged nephrons often show a variety of physical defects (Fig 2).

- Glomerular abnormalities: there is an increase in number of damaged glomeruli (glomerulosclerosis), typically characterised by progressive capillary collapse.
- Filtration membrane abnormalities: some nephrons display a progressive thickening and wrinkling of the filtration membrane in the glomerulus and the Bowman’s capsule. This effectively decreases the area of the renal filtering surface. Additionally, the filtration membrane becomes increasingly permeable, allowing large molecules such as proteins to collect in the filtrate and appear in the urine (proteinuria).

FIG 1. AGE-RELATED CHANGES TO THE RENAL SYSTEM

Increased collagen deposition. Reduced renal blood flow and glomerular filtration rate, loss of nephrons and abnormal nephron structure

Increased chance of urinary incontinence due to: reduced bladder elasticity and volume; loss of sphincter tone; poor bladder control

Shortened urethra in some women may increase chances of urinary tract infection. Prostatic hyperplasia in men may interfere with urine flow

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Acidosis: while the lungs play a role in acid-base balance. As they age, they become less efficient at clearing acidic/basic metabolites/ions. This is problematic in older people with diabetes as acidic molecules, such as ketones, may build up leading to acidosis. 

- Reduced creatinine clearance: creatinine is a molecule continually generated by the skeletal muscles. Serum levels of creatinine usually remain constant because the kidneys clear the molecule from the blood at the same rate as it is produced. By the age of 80, the renal clearance of creatinine is reduced by around 30% (Choudhury et al., 2004). Despite this, serum creatinine levels remain fairly constant well into old age because there is a gradual reduction in skeletal muscle mass so proportionately less creatinine is generated. 

- Polyuria and nocturia: the kidneys become less efficient at concentrating urine with age and also require a greater volume of water to excrete toxic waste products. The result is a gradual increase in urine volume leading to polyuria (frequent urination). Additionally, due to the changes in nephron structure described above, fluids drunk during the evening take longer to be processed, leading to nocturia (frequent nocturnal urination). This often disrupts sleeping patterns in older people. 

- Reduced clearance of toxic metabolites: special care must be taken with drugs that are excreted/eliminated in the urine. Dosages of water-soluble drugs such as certain antibiotics, amphetamines and digitalis may have to be adjusted in line with renal function to avoid toxic accumulation.

- Reduced filtration: the reduced renal function to avoid toxic accumulation. Digitalis may have to be adjusted in line with renal function to avoid toxic accumulation.

- Thickened filtration membrane 

- Reduced glomerular blood flow 

- Reduced filtration 

- Glomerular degeneration 

Reduced and fine control over salt reabsorption potentially contributing to electrolyte imbalances 

Tubule abnormalities: some kidney tubules gradually degenerate and are replaced by scar tissue (tubulointerstitial fibrosis). This decreases the total tubular area available for the reabsorption of useful materials such as glucose, amino acids and salts. The distal convoluted tubules often decrease in size and may display small pouches (distal diverticula), which can develop into fluid-filled cysts, increasing the risk of infection and pyelonephritis.

**REFERENCES**


**PHYSIOLOGICAL CHANGES**

There are significant reductions in renal function in older people. Even in the absence of disease, some individuals over the age of 65 have 60% renal function compared with young adults (Razzaque, 2007). This gradual decline has major health implications, particularly when long-term conditions and circulatory problems are present.

Common physiological changes include:

- Electrolyte imbalance: the reduced renal blood flow and GFR, together with the gradual loss in nephron numbers, reduces the kidneys’ ability to maintain the major electrolytes (sodium, potassium, calcium and chloride) within optimal physiological ranges. Since these salts play a major role in maintaining blood pressure and generating action potentials (nerve impulses), older people may have problems with hypertension/hypotension and an increased risk of becoming confused. 

- Acidosis: while the lungs play a role in regulating the blood pH, only the kidneys are able to excrete acidic/basic molecules directly and are the ultimate organs of the physiology of ageing:

**Post-rerenal changes**

As the bladder ages, it gradually loses elasticity due to an increase in collagen fibres. This typically reduces its holding capacity from around 600ml to 250ml (Siroky, 2004), exacerbating the problems of polyuria and nocturia.

The urinary sphincter often weakens with age and this may lead to urinary incontinence – a problem often compounded by age-related changes in the nervous system (see part 5 in this series), which reduce conscious control over the process of micturition (urination).

In women, the urethra may shrink, effectively becoming shorter. This may increase the chance of urinary tract infections (particularly cystitis) in older women. The benign enlargement of the prostate gland (prostatic hyperplasia) experienced by many men in middle and old age often compresses the urethra, making micturition difficult.

Little can be done to slow the age-related changes to the renal system. Fortunately the kidneys have a built-in redundancy (the renal reserve) and, in the absence of disease, they usually function adequately throughout life.

**NEXT WEEK**

The physiology of ageing: part 5 – the nervous system