



Anatomy and Physiology of Ageing

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Tutorial Questions

1. Why do elderly patients have decreased arterial oxygen tension on blood gas analysis when compared to younger patients?
2. What physiological changes to the cardiovascular system occur in the elderly?
3. Why are elderly patients at increased risk of hypotension during induction of anaesthesia?
4. What are the effects of ageing on skin, bones and joints and what implications do these changes have for the anaesthetist?

Introduction

The elderly population is increasing in size as people are living longer due to advances in medical science and improvements in standards of living. In the western world people over 65 years of age represent approximately 15% of the population and almost half of these individuals will present to hospital for a surgical procedure. Elderly patients have higher rates of hospital morbidity and mortality compared to younger patients. This increased risk is related to the normal physiological processes of ageing and increased prevalence of coexisting systemic disease.

As a person ages, their anatomy and physiology undergo many changes that become more apparent with increasing chronological age. Ageing is a progressive physiological process that is characterised by degeneration of organ systems and tissues with consequent loss of functional reserve of these systems. Loss of these functional reserves impairs an individual's ability to cope with physiological challenges such as anaesthesia and surgery.

Individuals of the same chronological age may differ significantly in the rate and severity of functional decline. Patients who maintain greater than average functional capacity are considered 'physiologically young' and those whose function declines at an earlier age appear to be 'physiologically old'.

The important anatomical and physiological changes that occur in the elderly are considered below.

Respiratory System

Lung and chest wall compliance decrease with advancing age. Total lung capacity (TLC), Forced Vital Capacity (FVC), Forced Expiratory Volume in 1 second (FEV₁) and Vital Capacity are all reduced as people age. Residual Volume (RV) increases and Functional Residual Capacity (FRC) remains unchanged. These changes occur as a result of reduction in elastic support of the airways and leads to increased collapsibility of alveoli and terminal conducting airways.

	Approximate values for 70 Kg 40 y/o male (Litres)	Effect of advancing age
TLC	6.0	Reduced
FVC	4.5	Reduced (4.0 aged 70)
FEV₁	4.0	Reduced (3.0 aged 70)
RV	1.5	Increased
FRC	2.5	Unchanged

By the age of 65 years closing capacity typically encroaches into tidal volume during normal tidal ventilation. This results in ventilation perfusion mismatch and reduced arterial oxygen tension. Arterial oxygen partial pressure can be estimated by the following equation.

$$\text{PaO}_2 = 13.3 - (\text{age}/30) \text{ kPa} \quad \text{or} \quad \text{PaO}_2 = 100 - (\text{age}/4) \text{ mmHg}$$

Arterial carbon dioxide tension is a function of alveolar ventilation and is not altered by ageing alone.

Atelectasis, pulmonary emboli and pneumonia are common post-operative complications in the elderly. These complications are increased in smokers, patients with chronic chest disease and those undergoing abdominal or thoracic surgery.

With advancing age, loss of elastic tissue around the oropharynx can lead to collapse of the upper airway. Sleep or sedative states may result in partial or complete obstruction of the airway. A progressive increase in the number of episodes of arterial desaturation during sleep occurs with advancing age and a history suggestive of obstructive sleep apnoea should be sought in older patients.

Patients are often edentulous making bag-mask ventilation difficult. Adjuvant airway devices such as an oropharyngeal airway help maintain an open airway during anaesthesia. Osteoarthritic changes may limit cervical spine flexibility and can make tracheal intubation more difficult. Care must be taken to avoid stressing the cervical spine as fragile ligaments and bones may be injured when subjected to mechanical forces.

Cardiovascular system

Large and medium sized vessels become less elastic and therefore become less compliant with age. This results in raised systemic vascular resistance and hypertension, which in turn may lead to left ventricular strain and left ventricular hypertrophy. Cardiac output falls by 3% per decade which is due to reduced stroke volume and ventricular contractility. The reduction in cardiac output with age increases the arm-brain circulation time for drugs and means intravenous anaesthesia is achieved more slowly and with reduced doses of anaesthetic agent. Cardiac conducting cells decrease in number making heart block, ectopic beats, arrhythmias and atrial fibrillation more prevalent. Since atrial contraction contributes approximately one third of the volume towards normal ventricular filling, patients with atrial fibrillation suffer a reduction in cardiac output of about 30%.

Catecholamine β adrenergic receptors in the myocardium are down regulated in the elderly resulting in a decreased responsiveness to catecholamines and sympathomimetic agents. The non-compliant vascular systems may result in reduced efficacy of vasoconstricting drugs such as ephedrine and metaraminol. There is global impairment of autonomic homeostasis and impaired carotid baroreceptor response such that the heart rate cannot always respond to maintain arterial blood pressure. Postural hypotension is common in the elderly population and may be exacerbated by diuretics, antihypertensive drugs and hypovolaemia.

Ischaemic heart disease is common in older patients, especially in smokers and diabetics. Since activity may be limited by poor mobility and other co-morbid features, symptoms such as angina or exertional dyspnoea may not be detectable. It is important that even without objective evidence of coronary heart disease *all* elderly patients should be considered at increased cardiovascular risk.

Structural heart lesions such as valvular heart disease are common. In the developing world, rheumatic heart disease is the commonest cause of valvular heart disease and usually affects the mitral valve. In the western world calcification of the aortic valve leading to aortic sclerosis is more prevalent.

Intravenous and inhalational agents depress cardiac and vascular smooth muscle contractility and may impair the baroreceptor response to hypotension. Hypotension should be anticipated with much greater frequency on induction of general anaesthesia.

Neuroaxial regional anaesthesia techniques are usefully employed in this patient group however these techniques may result in significant hypotension. This said, elderly patients often tolerate spinal anaesthesia well, as the non-elastic vascular tree is not as susceptible to vasodilatation caused by sympathetic blockade compared to younger patients.

Renal System

Glomerular filtration rate is thought to decrease by 1% per year over the age of 20 years due to a progressive loss of renal cortical glomeruli. A reduction in renal perfusion secondary to reduced cardiac output and atheromatous vascular disease leads to a decline in renal function. In addition diabetes mellitus is increasingly common, as is the use of nephrotoxic drugs such as non-steroidal anti-inflammatory drugs (NSAID's) and angiotensin converting enzyme inhibitors (ACE inhibitors). Prostatism in males can lead to obstructive nephropathy and dehydration is common in the elderly especially during illness.

Laboratory results may be deceptively normal in the elderly since muscle bulk decreases with age resulting in reduced creatinine production. A small rise in the creatinine level may therefore indicate significant renal impairment. Creatinine clearance is a more useful test of renal function and can be calculated from a 24-hour urine collection. An estimation of creatinine clearance can be derived using a patient's age, weight and gender using the modified Cockcroft-Gault formula.

$$\text{Creatinine Clearance (ml/min)} = \frac{(140 - \text{age}) \times \text{Weight (Kg)} \times \text{Constant}}{\text{Serum Creatinine } (\mu\text{mol/L})}$$

Constant for males = 1.23

Constant for females = 1.04

Renal impairment may lead to a reduced ability to excrete or conserve fluids, electrolyte imbalance and a reduction in the clearance of renally excreted drugs.

Central Nervous System

Cerebrovascular disease is common in the elderly secondary to diffuse atherosclerosis and hypertension. Neuronal density is reduced by 30% by the age of 80 years.

Cognitive impairment occurs frequently, common causes include Alzheimer's disease, multiinfarct dementia, Parkinsonism and chronic alcoholism. These disorders can lead to difficulties in communication, patient compliance and with consent to surgical and anaesthetic procedures.

It is well known that hospitalisation, anaesthesia and surgery can lead to deterioration in cognitive function which is thought to be multifactorial in origin. Causes include change of environment, medication, electrolyte imbalance, cerebral emboli and sepsis.

Visual and hearing impairment are very common in elderly people and can also lead to difficulties in communication.

Autonomic neuropathy may lead to impaired baroreceptor response and haemodynamic instability as well as delayed gastric emptying and increased risk of gastric aspiration.

Endocrine / Metabolic

The basal metabolic rate falls by 1% per year after the age of 30. Fall in metabolic activity and reduced muscle mass may cause impaired thermoregulatory control. Hypothermia peri-operatively can lead to shivering with increased oxygen consumption, vasoconstriction and catecholamine release and should be avoided if at all possible.

Approximately 25% of patients over 85 years have Non-Insulin Dependent Diabetes Mellitus (NIDDM). Diabetes leads to renal impairment, cardiovascular disease, neuropathy and retinopathy. Elderly patients also have an increase in thyroid disorders, osteoporosis and nutritional disorders.

Musculoskeletal System

Arthritis is extremely common and leads to pain and reduced mobility in affected individuals. Bones and joints may be deformed, making regional anaesthesia techniques difficult or even impossible. Osteoporosis occurs especially in females, immobile patients and those with a history of steroid use. Much care must be taken when moving and positioning patients so as to avoid exacerbating joint pain or causing fractures or dislocations. Prominent bony areas are susceptible to skin breakdown and pressure sores.

Skin

Elderly patients tend to have thin skin and fragile subcutaneous blood vessels and therefore patients tend to bruise easily. Achieving and securing venous access can be difficult and problems of extravasation of fluid or drugs can occur if infused under pressure. Care should be taken on transferring patients to avoid skin abrasions.

Pharmacology

Reduced cardiac output results in delayed onset of intravenous anaesthesia. Reduced total body water and increased adipose tissue leads to an altered volume of distribution of some drugs. Plasma proteins are reduced resulting in decreased protein binding and increased free drug availability. Minimum alveolar concentration (MAC) decreases by approximately 6% per decade for all inhaled anaesthetics. $MAC_{(age)}$ can be calculated by the following equation:

$$MAC_{(age)} = a \times 10^{bx}$$

$x = \text{Age} - 40\text{years}$

$b = -0.00269$

$a = \text{MAC at age 40years (halothane 0.75\%, isoflurane 1.17\%, enflurane 1.63\%, sevoflurane 1.8\%, desflurane 6.6\%)}$

Elderly patients have an increased sensitivity to CNS depressant drugs and so drug doses need to be modified accordingly. Patients also have reduced hepatic and renal function leading to slower metabolism and elimination of drugs.

Many patients take multiple medications on a regular basis and the effects of these medications on the individual's physiology must be taken into account.

Further Reading

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