Section 1

Basic Science Related to Operation Theatre Technology

CHAPTER

1

Introduction to Anatomy and Physiology of Human Body

The human body can be considered as a highly technical and sophisticated machine that operates as a single unit consisting of a number of systems, which work independently.

Anatomy and physiology are the branches of medical science, deal with structures and functions of the different parts of the body, respectively.

STRUCTURAL ORGANIZATION OF THE HUMAN BODY

Atom

The most fundamental structure of a human body is chemical and atom is the smallest part of it. Examples: Carbon, hydrogen and oxygen atoms.

Molecules and Macromolecules

- ★ Atoms combine to form molecules such as H₂O and CO₂. Molecules combine and form macromolecules such as carbohydrates, lipids and proteins.
- Various combinations of these macromolecules develop nucleus, mitochondria, ribosomes, Golgi apparatus, etc. Each of them plays a very important and specific role within a cell.

Cells

They are the smallest independent units of the human body. There are different types of cells depending upon the specialized job performed by them. ➤ Different types of cells can be distinguished microscopically by their shapes, sizes and dye they absorb on staining at the laboratory.

Tissues

Cells with similar structures and functions are found together and form tissues. Examples: Connective tissue, epithelial tissue, muscular tissue and nervous tissue.

Organs

They are made of different types of tissues and are assigned to carry out a specific function. Examples: Stomach, brain and heart.

Systems

System consists of a number of organs contribute together to carry out one or more survival needs of the body (Table 1.1).

Table 1.1: Activities of different systems				
Survival need	Activities of systems			
Communication	Nervous system Endocrine system			
Transport	Cardiovascular system Blood			
Intake of raw materials and elimination of waste products	Gastrointestinal system Respiratory system Excretory system			
Protection and survivals	Skin Musculoskeletal system Reproductive system			

BODY CAVITIES

Body cavities contain and protect different vital organs of the body. There are four body cavities—cranial cavity, thoracic cavity, abdominal cavity and pelvic cavity.

Cranial Cavity

The cranial cavity is consisting of bones of the skull which protects brain.

Boundaries

- ➤ Anteriorly—1 frontal bone
- **x** Laterally −2 temporal bones
- ➤ Posteriorly—1 occipital bone
- Superiorly —2 parietal bones
- **▼** Inferiorly —1 sphenoid and 1 ethmoid bone

Thoracic Cavity

Thoracic cavity is situated in the upper part of the trunk. It contains following organs.

- ★ A part of the gastrointestinal system oesophagus
- Part of the respiratory system—trachea, bronchi and lungs
- ➤ Part of the cardiovascular system—heart, aorta, superior and inferior vena cava and other major blood vessels.

Boundaries

- ★ Anteriorly—sternum and costal cartilage of ribs
- ➤ Laterally twelve pairs of ribs and intercostal muscles
- ➤ Posteriorly—thoracic vertebrae
- ➤ Superiorly—structures forming the root of the neck
- ▼ Inferiorly diaphragm muscle

Abdominal Cavity

It is located in the middle part of the trunk. It contains following organs.

- ▼ Most of the gastrointestinal system stomach, small and large intestine, liver, gallbladder, bile ducts and pancreas
- ▼ Part of the excretory system—two kidneys and ureters
- Other organs—spleen, lymph nodes and adrenal glands

Boundaries

- **▼** Superiorly—diaphragm muscle
- Anteriorly—muscles forming anterior abdominal wall
- Posteriorly—lumbar vertebrae and muscles forming posterior abdominal wall
- ➤ Laterally—lower ribs and muscles of the abdominal wall
- **▼** Inferiorly—continues with the pelvic cavity.

Regions of Abdominal Cavity

For a better understanding of the position of structures, the abdominal cavity is divided into 9 regions by two vertical and two horizontal lines (Fig. 1.1).

- ➤ Right hypochondriac region
- **▼** Epigastric region
- ▼ Left hypochondriac region
- x Right lumbar region
- ▼ Umbilical region
- ▼ Left lumbar region
- × Right iliac fossa
- ➤ Hypogastric region
- ▼ Left iliac fossa

Anatomical Terminology (Fig. 1.2)

1. **Terms related to relative position of a part of body:** Different terms used to describe the position of a particular part of body in relations to other parts:

Term	Meaning
Superior	Above or nearer to head
Inferior	Below or farther from head
Medial	Nearer to midline
Lateral	Farther from the midline or towards the side of the body
Proximal	Nearer to the point of attachment of a limb
Distal	Farther from the point of attachment of a limb
Anterior or ventral	Nearer to the front of the body
Posterior or dorsal	Nearer to the back of the body
Cephaloid or cephalic	Nearer to head
Caudal	Nearer to tail

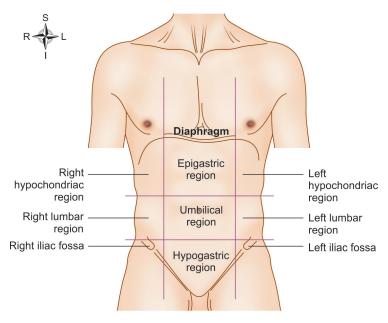


Fig. 1.1: Abdominal regions

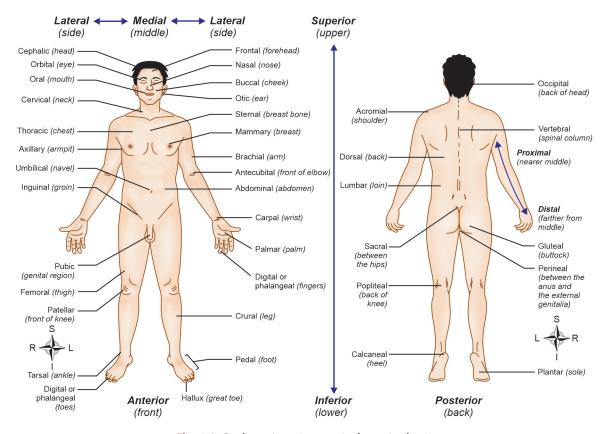


Fig. 1.2: Body regions (anatomical terminology)

2. Terms related to body planes:

- Median plane: Body is divided longitudinally through the midline into right half and left half.
- Coronal plane: Body is divided longitudinally into two equal halves anterior and posterior
- * Transverse plane: Transverse section divides the body into upper part and lower part. A transverse section may be at any level such as transthoracic, transabdominal or transcranial.

3. Terms used to describe various parts of the body:

- ▼ Cranial—skull
- ▼ Nasal—nose
- ▼ Frontal—forehead
- ▼ Orbital—eve
- **x** Facial−face
- ▼ Cervical—neck
- ▼ Cephalic—head
- × Buccal−cheek
- × Oral−mouth
- ▼ Otic—ear
- Axillary—armpit
- ▼ Brachial—upper arm
- Antecubital—anterior elbow
- ▼ Carpal—wrist
- ▼ Digital—finger
- ▼ Thoracic—chest
- ▼ Abdominal—abdomen
- **x** Umbilical—navel
- ▼ Inguinal groin
- ➤ Pubic—genital region
- **x** Gluteal−buttocks
- ▼ Femoral—thigh
- × Patellar − front of knee
- ▼ Tarsal—ankle
- ▼ Popliteal—back of the knee
- × Plantar—sole

ENVIRONMENT OF THE HUMAN BODY

External Environment

Environment surrounds the body is the source of oxygen and nutrients for the body. Waste products are excreted into external environment. The skin is a barrier between the body and the external environment.

Internal Environment

It is the water-based medium in which cells exist. This is called tissue fluid or interstitial fluid. The composition of the internal environment is maintained at a stable state, which is called homeostasis.

BODY FLUID COMPARTMENTS

Body fluid constitutes 60% of the total body weight. They are mainly distributed in the intracellular and extracellular compartments.

- ➤ Extracellular fluid: Water present outside the cells is extracellular fluid. It is about one-third of total body fluid distributed into interstitial space and plasma.
- ➤ Intracellular fluid: It constitutes about twothirds of total body fluids and presents within the cells.
- **▼ Others:** CSF, GI secretions, serous fluids.

Water Balance

Regulation of water balance includes the regulation of the solute contents and the volume of the fluid. Aldosterone, antidiuretic hormone and rennin-angiotensin system are main regulators of water balance.

- x Total water intake by an adult −2500 ml/day
 - * Source:
 - ▲ Water ingestion 60%
 - ▲ Intake through food —30%
 - ▲ Cell metabolism 10%
- ➤ Total output of water 2500 ml/day
 - **★** Urine from the kidney 60%
 - **★** Evaporation through the skin −28%
 - **★** Perspiration—8%
 - **★** Faeces 4%

Dehydration

Dehydration is a clinical condition characterised by depletion of total body water. It may be due to insufficient intake of water or more commonly excessive loss of water. Common causes of dehydration are diarrhea, vomiting, excessive sweating and burn.

Treatment of dehydration includes plenty of water intakes orally or intravenously.

Overhydration

Overhydration is a clinical condition characterised by increase in total body water. It is not necessary that all compartments are overhydrated. It may occur due to excessive intake of salt-free fluids, renal failure and hypoproteinemia. Water intoxication is a common complication of transurethral resection of prostate (TURP) operation.

Treatment of overhydration or water intoxication includes treatment of the cause, fluid restriction, diuretics and administration of hypertonic solution.

Electrolyte Balance

Electrolytes are well-distributed in the different compartments of body fluid. Total concentration of cations and anions in each compartment is equal and thus maintains electrolyte equilibrium. Composition of electrolytes is different in extracellular and intracellular compartments (Table 1.2).

Regulation of Electrolyte Balance

Kidney plays a key role in maintenance of fluid and electrolyte balance. Regulation is mainly achieved by three hormones—aldosterone,

antidiuretic hormone (ADH) and, renninangiotensin. In response to increased blood volume, atrial natriuretic factor (ANF) is liberated from the heart. ANF acts on kidney and increases glomerular filtration rate, sodium excretion and urine output.

Acid-Base Balance

Maintenance of acid-base balance or pH is essential for the normal function of cells. Alteration in pH may cause disruption of cellular functions or even death. Normally, the pH of plasma or blood is maintained within a narrow range of 7.35–7.45.

Maintenance of Acid-base Balance

Acid-base balance or pH is maintained by three defensive mechanisms of body.

- **x** Blood buffers
- **▼** Respiratory mechanism
- ▼ Renal mechanism

Blood Buffers

The blood contains three buffer systems—bicarbonate, phosphate and protein buffer system. Bicarbonate is mostly extracellular buffer, phosphate is intracellular buffer and protein is the buffer system of blood.

Table 1.2: Composition of electrolytes in the body fluid compartments					
Compartment	Cations	Concentration in mEq/litre	Anions	Concentration in mEq/litre	
Extracellular fluid compartment	Na ⁺	142	Cl-	103	
	K ⁺	5	HCO ₃	27	
	Ca ²⁺	5	HPO ₄ ²⁻	2	
	Mg ²⁺	3	SO ₄	1	
			Proteins	16	
			Organic acids	6	
	Total	155		155	
Intracellular fluid compartment	K ⁺	150	HPO ₄ ²⁻	140	
	Na ⁺	10	HCO ₃	10	
	Mg ²⁺	40	Cl ⁻	2	
	Ca ²⁺	2	SO ₄	5	
			Proteins	40	
			Organic acids	5	
	Total	202		202	

Common Electrolyte Imbalance (Table 1.3)

Table 1.3: Types of electrolyte imbalance						
Electrolyte	Type of electrolyte imbalance	Causes	Treatment			
Sodium	Hyponatremia: Serum Na ⁺ <135 mEq/L	Hypovolemic hyponatremia * Vomiting * Diarrhea * Burn * Trauma * Excessive diuretics Hypervolemic hyponatremia * Cardiac failure * Cirrhosis * Renal failure Euvolemic hyponatremia * Glucocorticoid deficiency * Hypothyroidism * TURP syndrome	★ Mild asymptomatic case with hypovolemia: Intravenous infusion of normal saline ★ Mild asymptomatic case with hypervolemia: Loop diuretics to remove excess water ★ Severe hyponatremia: Hypertonic saline infusion to raise serum Na+1mEq/L for first 3-4 hour and not more than 10 mEq/L in 24 hour.			
	Hypernatremia: Serum Na ⁺ >145 mEq/L	Associated with water loss or sodium gain Inadequate water intake Excessive salt ingestion Near drowning in sea water Diuretics Cushing syndrome	 x Sodium restriction x Salt-free water ingestion x IV infusion of 5 % dextrose x Desmopressin acetate in diabetes insipidus 			
Potassium	Hypokalemia: Serum K ⁺ <3.5 mEq/L	 Reduced dietary intake Increased GIT loss Cushing syndrome Prolonged steroid therapy 	 Oral drinks of potassium rich fluid IV replacement with KCl in severe case 			
	Hyperkalemia: Serum K+ >5.0 mEq/L	 Renal failure Drug's toxicity such as digitalis and ACE inhibitors latrogenic 	 IV glucose insulin Calcium gluconate intravenously NaHCO₃ infusion to promote shifting of K⁺ inside cells 			
Calcium	Hypocalcemia: Serum Ca ²⁺ < 8.4 mg/dl or ionized calcium <1.2 mg/dl	 Hypoparathyroidism Hypoalbuminemia Hypomagnesemia Nutritional deficiency of Vitamin D₃ 	x IV 10% calcium gluconate 10 ml slowly over 10 minutes x Chronic case is treated with calcium salt.			
	Hypercalcemia: Serum Ca ²⁺ >11 mg/dl or ionized calcium >5.2 mg/dl	HyperparathyroidismVitamin D intoxicationMalignancy: Lung, breast	∗ Frusemide after correction of volume∗ Calcitonin∗ Steroid			

Respiratory Mechanism

Respiratory rate is controlled by respiratory centre, located at medulla of the brain.

Respiratory centre is very sensitive to the pH of blood. Fall in pH stimulates respiratory centre and causes hyperventilation. Hyperventilation

increases carbon dioxide excretion via lungs thus tries to increase pH of the blood.

Renal Mechanism

Enzyme carbonic anhydrase is primarily responsible for renal regulation of pH. It is done by following mechanisms.

- ➤ Excretion of H⁺ ions
- **▼** Reabsorption of bicarbonate
- **x** Excretion of titratable acid
- Excretions of ammonium ions

Disorders of Acid-base Balance

Acid-base disorders may be classified as:

- × Acidosis (↓pH)
 - * Metabolic acidosis—due to decrease in bicarbonate
 - * Respiratory acidosis—due to increase in carbonic acid (H₂CO₃)
- × Alkalosis (↑pH)
 - * Metabolic alkalosis—due to increase in bicarbonate
 - * Respiratory alkalosis due to decrease in carbonic acid

To counteract the acid-base disturbances, homeostatic mechanism of body activates and tries to maintain pH within normal range. This is called compensatory acid-base disorders.

Blood Gas Analysis

Arterial blood gas analysis is one of the most common investigations in critically ill patients in intensive care unit, emergency, operation theatre and postoperative care unit. It is done to detect acid—base disturbances and effects of therapeutic interventions.

Arterial blood sample can be collected from radial, brachial or femoral artery by single prick or permanent arterial cannulation. Most preferred site is radial artery just above the wrist joint.

Procedure

- ➤ Perform Allen's test to determine presence of collateral circulation between ulnar and radial arteries of the hand. Aim is to ensure adequate blood supply of hand by ulnar artery if, radial artery is blocked due to spasm, pressure or haematoma.
- ➤ Place arm on the arm-board with palmar side up and wrist dorsiflexed.
- ➤ Locate radial artery just above the wrist joint by feeling arterial pulsation.
- ➤ Clean the area selected for arterial cannulation with antiseptic solution.
- ➤ Feel radial artery with left hand. Stabilize it by keeping the skin over it tight.
- ➤ Hold radial cannula with right hand and puncture skin at an angle of 45–60° (90° for femoral artery).
- ➤ Advance catheter till flash of blood is observed in catheter. Connect it with pressure IV tubing.
- ➤ Secure arterial line with tape and dressings.
- During collection of blood sample, the arterial blood pressure should be allowed to push the plunger of the syringe and fill it. This prevents mixing of blood with air and wrong analysis.
- ➤ Arterial blood sample is collected in a syringe containing heparin as an anticoagulant. It should be analysed immediately or within 1 hour if stored at 0–4°C.

Components of ABG Analysis

The components of ABG analysis are given in Table 1.4.

Table 1.4: Components of ABG analysis				
Components	Description	Normal value		
рН	Measure hydrogen ion levels in the blood and detect acid-base balance	7.35–7.45		
PaO ₂	Partial pressure of oxygen in the arterial blood. It detects oxygen pick up and supply by lungs	85–100 mm of Hg		
SaO ₂	Arterial oxygen saturation	95–100%		
PaCO ₂	Partial pressure of carbon dioxide in arterial blood. It reflects alveolar ventilation and its diffusion across the alveolar capillary membrane.	35–45 mm of Hg		
HCO ₃	Calculated concentration of bicarbonate in arterial blood.	22-26 mEq/L		

Interpretations of ABG

- Assess oxygenation; low PaO₂ and SaO₂ indicate inadequate oxygenation. Treat the underlying cause and increase inspired oxygen concentration.
- ➤ Determine the pH to detect any abnormality. Acidosis if pH is less than 7.35 and alkalosis if pH is more than 7.45.
- ➤ Determine the cause of abnormal pH. It is either respiratory or metabolic in origin.
- ➤ Determine the effect of compensatory mechanism; for example in case of metabolic acidosis, low bicarbonate level is associated with low pH. As a compensatory mechanism hyperventilation takes place and CO₂ level falls. Hence, due to this compensation fall in pH is less as compared to bicarbonate level
- ★ Serum electrolytes such as Na⁺, K⁺, Ca⁺, Cl⁻
 are also estimated to know the anion gap
 which is altered in acid–base disturbance.

COMMON TERMINOLOGY ASSOCIATED WITH THE DISEASE

- ▼ Aetiology: Cause of disease
- ▼ Pathogenesis: The main process causing disease
- ➤ Complications: Consequence which may occur with the progress of the disease
- **▼ Prognosis:** Likely outcome
- ▼ Acute: Sudden onset of disease
- **▼ Chronic:** Long-standing disorder
- ▼ Congenital: Disorder presents since birth
- **▼ Acquired:** Disorder develops after birth
- **➤ Communicable:** Disease spread from one person to other.

Multip

Multiple Choice Questions

1. Term "proximal" means:

- A. Farther from the point of attachment of a limb
- B. Nearer to the point of attachment of a limb
- C. Nearer to midline
- D. Farther from the midline

2. Cranial cavity_____

- A. Consists of 8 number of skull bones
- B. Protects brain
- C. Contains spleen, lymph nodes and adrenal glands
- D. Both A and B

3. Water balance of the body is regulated by:

- A. Aldosteron
- B. Antidiuretic hormone
- C. Rennin-angiotensin system
- D. All of the above

4. Treatment of water intoxication includes:

- A. Intravenous 5% dextrose infusion
- B. Intravenous half strength normal saline infusion
- C. Intravenous hypertonic saline infusion
- D. None of the above

5. Main cation present in the intracellular compartment is:

- A. Na⁺
- B. K⁺
- C. Mg²⁺
- D. Ca²⁺

6. Main anion of the intracellular compartment is:

- A. HPO₄ ^{2−}
- B. Cl
- C. HCO₃
- D. Protein

7. The most predominant anion in the extracellular fluids:

- A. Cl
- B. HCO₃
- C. HPO₄²⁻
- D. Protein

8. One of the serious complications of renal failure is:

- A. Hypokalemia
- B. Hyperkalemia
- C. Hyponatremia
- D. Hypernatremia

9. Causes of hypercalcemia is/are:

- A. Hypermagnesemia
- B. Vitamin D intoxication
- C. Hypoparathyroidism
- D. All of the above

- 10. Acid-base balance of the body is maintained by:
 - A. Blood buffer
 - B. Respiratory mechanism
 - C. Renal mechanism
 - D. All of the above
- 11. H⁺ ion is eliminated from the body by:
 - A. Lungs
 - B. Kidney
 - C. Stomach
 - D. None of the above
- 12. Normal pH value of blood is:
 - A. 7.45-7.55
- B. 7.46-7.53
- C. 7.35-7.45
- D. 7.25-7.32

- 13. The anion gap refers to the unmeasured plasma anion concentration and is represented by:
 - A. Proteins and organic acids
 - B. Phosphate and sulphate
 - C. Urate
 - D. All of them
- 14. What is the type of acid-base imbalance, if ABG report finds pH 7.25, PaCO₂ 55 mm Hg and bicarbonate 24 mEq/L:
 - A. Metabolic acidosis
 - B. Metabolic alkalosis
 - C. Respiratory acidosis
 - D. Respiratory alkalosis

Answers

1.B 2.D 3.D 4.C 5.B 6.A 7.A 8.B 9.B 10.D

11. B 12. C 13. A 14. C