"STUDY OF SERUM ELECTROLYTES AND BLOOD GLUCOSE IN CHILDREN ADMITTED TO PICU AND ITS CORRELATION WITH MAINTENANCE FLUIDS AND OUTCOME"

By

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In partial fulfilment of the requirements for the degree of

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In

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Under the guidance of

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ABSTRACT

INTRODUCTION

Disturbances in fluid and electrolytes are among the most common problems encountered in Pediatric ICU. They occur in many conditions, may remain unrecognized and result in morbidity and mortality irrespective of the primary condition. Early goal directed therapy and a thorough understanding of common electrolyte abnormalities is necessary to ensure their correction.

Fluid resuscitation should be aimed at restoration of normal hemodynamics and tissue perfusion. Many patients encounter secondary homeostatic imbalances that involve one or more of the following:-Sodium, Potassium, Calcium, Chloride, blood glucose. Abnormalities in the serum concentrations of these electrolytes could result from an underlying disease process; however, more frequently they are the result of complications, end organ injury or iatrogenic interventions such as fluids and electrolytes, medications and should therefore be anticipated and prevented.

Holliday-Segar equation remains the standard method for calculating maintenance fluid requirements. Deficit fluid is generally administered over first 24hours of hospitalization.

AIMS AND OBJECTIVE

To study the electrolyte status and blood glucose levels in children admitted in PICU at admission and at the end of 24hours.

To correlate above with fluids administered and outcome in terms of death, discharge.

MATERIAL AND METHODS

This was a prospective study conducted at Pediatric ICU of BLDEU's Shri B. M. Patil Medical College Hospital and Research Centre, Vijayapur from November 2015 to April 2017 and included 153 patients admitted in PICU. Under aseptic precautions, required amount of blood is collected in plain bulb. The blood containing bulbs are labelled and kept aside for serum separation. The bulbs are sent to laboratory without delay. Reports are collected and interpreted. Outcome in terms of electrolyte disturbance, discharge status or death was recorded.

RESULTS

The study group included a total of 153 patients aged between 1 month and >5 years, admitted to PICU. The mean age was 4.8 years. The male: female ratio was 1.2:1. Of the 153 patients admitted, 128 patients (83.7%) had electrolyte abnormality. Hypochloremia (51%) was the most common electrolyte abnormality, followed by Hyponatremia (31.4%), Hyperglycemia (25.5%), Hypercalcemia (19.6%), Hypocalcemia (19%), Hypokalemia (12.4%), Hypernatremia (7.8%), Hyperchloremia (7.8%), Hyperkalemia (6.5%), and Hypoglycemia (3.9%). Most common system involved was CNS (32.7%), followed by Respiratory illness (22.2%), gastrointestinal disease (19%), Infectious disease (18.3%), cardiovascular disease (5.9%), and Hematological diseases (2%). Use of DNS as maintenance fluid led to correction of the following electrolyte imbalances at the end of 24 hours: Hypoglycemia, Hypernatremia, Hypercalcemia and use of RL as maintenance fluid led to correction of Hypercalcemia, Hyponatremia, Hyperglycemia.

Out of the 153 patients, 96.1% were discharged, 3.3% were discharged against medical advice, 0.7% died.

CONCLUSION

Fluid and electrolyte abnormalities are very common in critically ill patients and can lead to fatal consequences.

Mixed electrolyte abnormalities are highly prevalent in expired PICU patients.

In view of these facts, a routine estimation of serum electrolytes should be considered in all patients getting admitted to PICU.

Our study results support the notion that isotonic maintenance fluid is safe in critically ill Paediatric patients.

Key words: PICU, Hypoglycemia. Hyperglycemia, Hyponatremia, Hypernatremia, Hypokalemia, Hyperkalemia, Hypocalcemia, Hypercalcemia, Hypochloremia, Hyperchloremia.

LIST OF ABBREVATIONS

%	Percentage
≤	Lesser than equal to
≥	Greater than equal to
PICU	Pediatric intensive care unit
ADH	Anti diuretic hormone
ATP	Adenosine triphosphate
AMP	Adenosine monophosphate
ANP	Atrial natriuretic peptide
PTH	Parathormone
AVP	Arginine vasopressin
BUN	Blood urea nitrogen
CBC	Complete blood count
Ca^{+2}	Calcium
Na^{+}	Sodium
K^{+}	Potassium
CaSR	Calcium sensing receptor
CAH	Congenital adrenal hyperplasia
CVS	Cardiovascular system

CNS	Central nervous system
ECF	Extracellular fluid
ECG	Electrocardiography
GFR	Glomerular filteration rate
HCl	Hydrochloric acid
$1,25(OH)_2D$	1,25-dihydroxy vitamin D
SIADH	Syndrome of inappropriate anti diuretic hormone secretion
RTA	Renal tubular acidosis
TBW	Total body water
SD	Standard deviation
UTI	Urinary tract infection
UV	Ultraviolet
WBC	White blood cells
NS	Normal saline
RL	Ringer lactate
EP	Isolyte P
½ NS	0.45% Normal saline
DNS	Dextrose normal saline

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INTRODUCTION

Disturbances of fluid and electrolyte homeostasis are commonly encountered in paediatric ICU[1].They occur in many conditions, may remain unrecognized and result in morbidity and mortality irrespective of the primary condition. Early goal directed therapy and a thorough understanding ofcommon electrolyte abnormalities is necessary to ensure their correction[2].

Fluid resuscitation should be aimed at restoration of normal hemodynamics and tissue perfusion. Many patients encounter secondary homeostatic imbalances that involve one or more of the following:-Sodium, Potassium, Calcium, Chloride, Blood glucose. Sodium and potassium are common electrolyte disorders and are associated with increased morbidity and mortality[3].

Sodium is the main cation of the ECF, and is the main determinant of extracellular osmolality[3]. Among all the electrolytes sodium is unique because water balance, not the sodium balance, which determines its concentration[4]. Serum sodium concentration normally ranges between 135-145 mEq/l.

When hyponatremia occurs, the fall in plasma osmolality stops the secretion of anti-diuretic hormone, and subsequent renal water excretion leads to an increase in the concentration of sodium. Though the water balance is usually regulated by osmolality, depletion in volume does not stimulate thirst, ADH secretion, and renal conservation of water. Depletion in volume takes an upper hand over osmolality; ADH secretion is stimulated due to depletion in the volume, even when the patient has hyponatremia[4]. Hyponatremia is serum sodium <135mEq/l.

Hypernatremia is defined as serum sodium >145mEq/l[4]. Hypernatremia in children admitted to hospital may be because of inadequate administration of water

(iatrogenic) or, by excessive sodium administration. Morbidity is significantly seen in moderate or severe hypernatremia.

Potassium is the principal intracellular cation. Serum potassium concentration ranges between 3.5-5 mEq/l[5]. Most of the body potassium is present in muscles[4].

Hypokalemia without a true deficit in potassium can result from redistribution into the cells in response to a beta-adrenergic stimulus, alkalosis, excess insulin or Rarer causes like familial hypokalemic periodic paralysis.

Hypokalemia has cardiovascular, neuromuscular and metabolic consequences including a propensity for dysarrthythmias, ileus, muscle weakness and effects on carbohydrate and protein metabolism.

Hyperkalemia without true overload (or even deficit) may result from measurement error (e.g. hemolysis in the sample), acidosis, insulin deficiency, or drugs such as digoxin, beta blockers and depolarizing muscle relaxants.

Hyperkalemia is dangerous because of its effects upon cell membrane potential and therefore upon cardiac rhythm (sinus arrest and ventricular fibrillation). The point at which such rhythm supervenes is unpredictable but depends upon the rate of rise of the serum level and the age/maturity of the patient.

Calciumis a divalent cationthat plays an important role in maintaining membrane potential and in various intracellular enzyme processes. Since about 99% of the calcium is in the bones[6], serum calcium concentration gives us poor information regarding the total body calcium.

The calcium level in the blood is maintained at a constant level by the actions of PTH, vitamin D and calcitonin acting on the GI tract, bones and the kidney. Normal serum calcium level is between 8.5-10.5mg/dl[5].

Deficiency or defects in the metabolism of vitamin D, absence or resistance to the actions of PTH are the two major mechanisms that result in hypocalcemia.

Hypercalcemia is defined as serum calcium >10.5mg/dl. While children comprise only 1% of patients with primary hyperparathyroidism, it is an important cause of hypercalcemia in older children. Gastrointestinal and neurological symptoms are common.

Chloride is the principal anion along with sodium in the extracellular fluid. Serum chloride concentration normally ranges between 96-106mEq/l[7]. Increase in the concentration of serum chloride can be due to addition of excess chloride to the ECF or by the removal or loss of water from this compartment, and vice-versa. Loss of chloride from the ECF or the addition of water to this compartment leads to decrease in the serum concentrations of chloride. Isotonic sodium chloride can be used to correct the total body chloride depletion.

Glucosevariability has potential effects on hydration and nutritional status. It indirectly leads to increased oxidative stress leading to cellular damage and apoptosis, the increased production of reactive oxygen species, such as peroxynitrite and superoxide has been postulated to be the major underlying mechanism for glucose induced micro vascular damage[8]. Through these micro vascular effects glucose variability may play larger role in acute physiological changes that occur among critically ill patients.

Hyperglycemia in PICU is associated with poor outcome in children. Mechanisms involved are increased inflammatory cytokine production, acute dyslipidemia, endothelial dysfunction, hyper coagulation and accelerated glucose toxicity leading to metabolic disturbances and increased cellular apoptosis. Hyperglycemia (blood glucose>126mg/dl) is common in critically ill children and values >180mg/dl are associated with mortality.

Hypoglycemia has been considered to be a possible cause of long term cognitive impairment. Hypoglycemia (blood glucose<70mg/dl), and glucose variability were associated with multiple organ dysfunction.

Maintenance fluids are given intravenously in children who cannot be fed orally. Holliday-Segar equation is the standard method for calculating maintenance fluid requirements[6]. Maintenance fluid contains water, glucose, sodium and potassium. Children lose water, sodium and potassium in urine, stool, skin, lungs. The losses are replaced by maintenance fluids, thereby preventing the development of dehydration and deficiency of electrolytes (mainly sodium or potassium).

In conjunction with the tremendous medical advances of the past century, an increasing number of hospitalized patients are dependent on parenteral fluids. Caring for children who have complex medical conditions has resulted un new challenges for prescribing parenteral therapy to maintain sodium and water hemostasis; hence majority of electrolyte disturbances occur in hospital setting.

AIMS AND OBJECTIVES

- To study the electrolyte status and blood glucose levels in children admitted in Paediatric ICU at admission and at the end of 24 hours.
- To correlate above with fluids administered and outcome in terms of death, discharge.

REVIEW OF LITERATURE

BODY FLUID

A relatively constant volume and a stable composition of the body fluid are essential for the maintenance of homeostasis.90% of the body weight in early fetal life is due to total body water, gradually decreases to 60% by 1 to 2 years and remains constant thereafter[4].

The total amount of body fluid volume and the total amounts of solutes as well as their concentrations are relatively constant during steady state conditions as required for homeostasis.

BODY FLUID COMPARTMENTS

Total body water is distributed in two main compartments:

1. intracellular fluid (30-40% of body weight),
2. extracellular fluid (20-25% of body weight).

The extracellular fluid is further divided into:

a. The plasma (5% of body weight) and
b. Interstitial fluid (15% of body weight) in the ratio of 1:3[4].

Water distributes between ECF and ICF compartments to achieve osmotic equilibrium. The water movement within the ECF compartment is determined by the capillary hydrostatic pressure and colloid osmotic pressure.

TBW (L) = 0.61 x weight (kg) + 0.251

INTRACELLULARFLUID COMPARTMENT.

About two- third is the ICF. The intracellular fluid is the fluid within the cells of the body. Potassium is the main solute of this compartment[4]. Other solutes are proteins, organic anions and phosphate.

ICF=TBW-ECF.

EXTRACELLULARFLUID COMPARTMENT.

The remaining one-third of the body water is outside cells, in the extracellular fluid compartment (ECF). The ECF is distributed between intravascular (plasma) and extravascular (interstitial) spaces (ratio of 1:3). A decrease in the ECF volume is seen after normal postnatal dieresis. Dehydration, anaemia, polycythemia, heart failure, hypoalbuminemia alter the volume of plasma water. There is a delicate equilibrium between the intravascular fluid and the interstitial fluid. Hydrostatic and oncotic pressures balance regulate the intravascular volume.Sodium and chloride are the main cation and anion of the extracellular fluid compartment. Since sodium is the principal extracellular solute, the ECF is determined primarily by the sodium content of the body and the mechanisms responsible for maintaining it.The amount of sodium is therefore very tightly regulated by modulation of renal retention and excretion in situations of deficient and excess ECF, respectively.

The ECF is calculated by, ECF (L) = 0.239 x Wt (kg) + 0.325

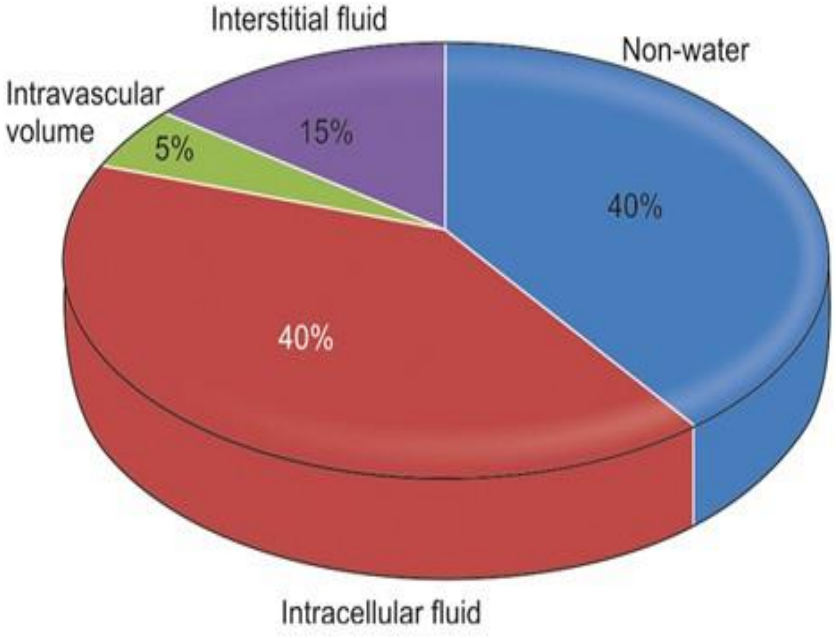


Figure1:Total body water distribution as a percentage in older children.

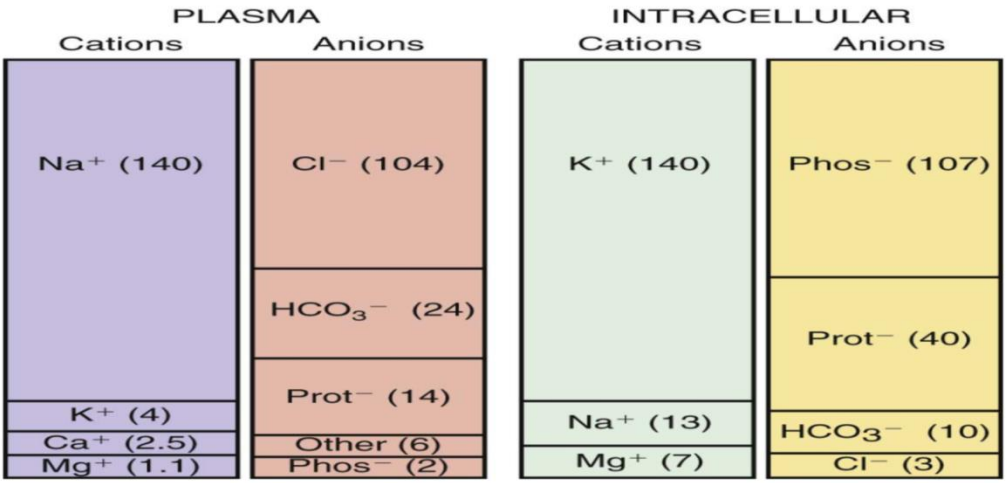


Figure2: Distribution of major cations and anions in ECF and ICF

OSMOLALITY

It is the solute concentration of a fluid. Normal plasma osmolality is 285-295 mOsm/kg, and it measured by the degree of freezing point depression.

The ECF and ICF are in osmotic equilibrium because of the permeability of the cell membrane to water. The change in osmolality in one compartment, leads to the movement of water leading to equalization of osmolality. This can lead to significant shift of water between the intracellular space and the extracellular space. Changes in osmolality can produce grave neurologic consequences and even death, principally due to water movement in and out of the brain.

Osmolality=2*[Na]+[glucose]/18+[BUN]/2.8

Glucose and BUN are measured in mg/dl. Dividing these values by 18 and 2.8 converts them to mmol/l and multiplication of the sodium values by 2 accounts for its accompanying anions (chloride and bicarbonate).

Effective osmolality=2*[Na]+[glucose]/18

The effective osmolality (tonicity) determines the osmotic force that is mediating the shift of water between the ECF and the ICF.

REGULATION OF OSMOLALITY:

Adjustment of water intake and excretion maintains normal plasma osmolality. The regulatory system is governed by different osmoreceptors in the hypothalamus that influence both thirst and the secretion of anti diuretic hormone.

Water intake is regulated by Osmoreceptors in hypothalamus

water loss is regulated by antidiuretic hormone from posterior pituitary

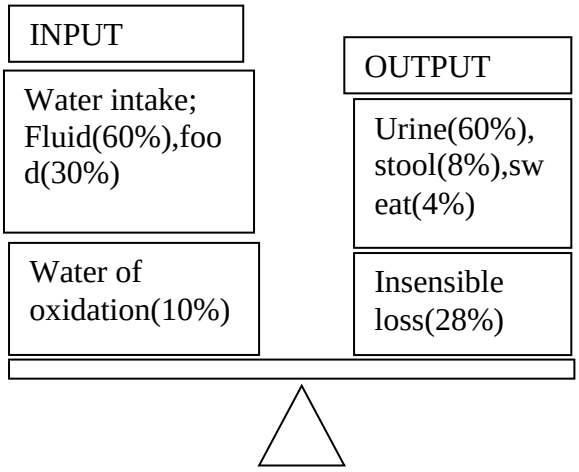


Figure 3: Balance of water intake and losses maintain normal plasma osmolality.

REGULATION OF VOLUME:

Asuitable intravascular volume is essential for survival; both volume depletion and volume overload may cause significant morbidity and mortality. Since sodium is the main extracellular cation, adequate body sodium is necessary for maintenance of intravascular volume[4].

Causes of extracellular fluid volume expansion are:

1. Primary renal sodium retention- acute kidney injury, advanced chronic kidney disease, primary glomerular diseases
2. Secondary renal sodium retention due to reduced effective arterial blood volume depletion- cardiac failure, cirrhosis, nephritic syndrome, idiopathic edema.

Causes of extracellular fluid volume depletion are:

1. RENAL CAUSES: diuretic use, tubular disorders like Bartter's and Gitelman's syndromes or acute kidney injury, hormonal and metabolic disturbances like Addison's disease or diabetes mellitus.
2. EXTRARENAL CAUSES: gastrointestinal losses due to vomiting or diarrhoea, dermal losses, third space losses due to ascites or pleural effusion, haemorrhage.

Volume regulation (baroreceptors in the great vessels) helps in maintaining the water balance. Decrease in the body water content leads to increased AVP secretion leading to renal conservation of water and vice- versa, non osmotic AVP release, activation of sympathetic system and renal conservation of water by renin-angiotensin- aldosterone system.

SODIUM:

Sodium is the main cation of the ECF and is the primary determinant of extracellular osmolality.Hence,necessary for maintenance of intravascular volume.

Total body sodium is present mostly in the bones (>40%)[4], interstitial and intravascular spaces. Na+K+ATPase maintain the low intracellular sodium (10mEq/l), by exchanging intracellular sodium for extracellular potassium.

Intake:

Daily sodium requirement is 2 to 3 mEq/kg body weight.Occasionally, child can have salt craving because of an underlying salt wasting renal disease. Absorption of sodium occurs through the gastrointestinal tract and the presence of glucose enhances sodium absorption due to the presence of a co transport system.

Excretion:

Main site for sodium excretion are the kidneys. Remaining excretion occurs through the stool and the sweat.

REGULATION OF SODIUM BALANCE:

The sensing mechanisms that are responsible for maintenance of sodium balance are as follows: [9, 10]

Afferent Mechanisms:

Within the central circulation are sensors in the right and left atria. Distention of either atrium activates neurons that are responsive to mechanical stretch or wall tension. There is increased release of a humoral factor atrial natriuretic peptide. ANP

stimulates diuresis, natriuresis and vasorelaxation. Volume sensors in the ventricles also contribute to the maintenance of ECF volume.

Activation of baroreceptors in the carotid artery and the juxtaglomerular apparatus in the kidney stimulates renal sodium excretion to minimize increase in effective ECF volume. The hepatic vascular bed also contains volume responsive sensors that regulate renal sodium excretion. Finally there are central nervous system sensors that stimulate natriuresis following infusion of hypertonic saline. The hypothalamus may secrete a low molecular weight nonpeptide natriuretic substance that inhibits the sodium - potassium ATPase pump[9].

Efferent Mechanism:

Glomerular filteration of Sodium occurs under normal conditions, changes in GFR do not affect sodium homeostasis.

A constant fraction of the filtered load of the sodium is reabsorbed in the proximal tubules despite transient, variations in GFR. This balance is called "glomerular tubular balance". The factors that affect the GFR and promote sodium reabsorption in response to a decreased ECF volume such as dehydration, hemorrhage or activation of sympathetic renal nervous system and stimulation of the renin angiotensin system.

When expansion of ECF volume occurs atrial natriuretic peptide is released into the circulation and cause increase in urinary loss of sodium; in part as a response to increase GFR.

Tubular reabsorption of sodium:

Most of the sodium reabsorption occurs in the proximal tubule and loop of Henle delivers a constant proportion of the filtered load of sodium to the distal nephron. Secondly, resabsorption of sodium in the distal tubules and collecting ducts is the fine regulator of the final amount of sodium excreted, which closely matches the amount of sodium ingested.

Reabsorbed sodium is actively transported out of the cell across their basolateral membranes, which produces an osmotic gradient that causes the movement of an equivalent amount of water.

Sodium transport at the thick ascending limb is active. When sodium load in the loop of henle is increased most of the increased load is reabsorbed in the loop. Thick ascending limb of the loop of Henle absorbs 30%, distal convoluted tubule 7.8%, collecting tubule 2% and a total of 40% and 60% absorbed by proximal tubule.[12]

FACTORS REGULATING SODIUM EXCRETION:

1. Tubular reabsorption of sodium is regulated by the renin- angiotensin system by directly stimulating sodium reabsorption in the proximal tubule by angiotensin II and by the stimulation of aldosterone secretion by angiotensin II. Aldosterone secretion helps in sodium reabsorption in late distal convoluted tubule and collecting ducts. Aldosterone also increases potassium secretion leading to loss of potassium in urine[11].
2. Atrial natriuretic peptide released from cardiac myocytes, when the ECF volume increases and stretches atrial wall. ANP acts on kidney generally

antagonize the sodium retaining mechanism of the renin-angiotensin system and increase water and sodium excretion.

3. Prostaglandins also modulate sodium excretion by influencing the glomerular microcirculation and via direct effects on the tubule epithelium.
4. Nitric oxide modulates the renal arteriolar resistance that regulates glomerular filtration rate, and it contributes to the activity of the tubularglomerular feed back mechanism. Nitric oxide directly inhibits sodium transport via apical channel in cultured collecting duct cells[9].
5. Starling forces influence the movement of reabsorbed solute and water into the peritubular capillaries. Sum of starling force favours the movement of solute and water from the intercellular and interstitial space into the peritubular capillary.

CONTROL OF EXTRACELLULAR FLUID OSMOLARITY AND SODIUM CONCENTRATION:

The factors involved in the regulation of osmolarity of the extracellular fluid and sodium concentration are[13]:

1. Osmoreceptor -ADH system.
2. Thirst mechanism.
3. Role of angiotensin II and aldosterone.

1. Osmoreceptor-ADH feedback system

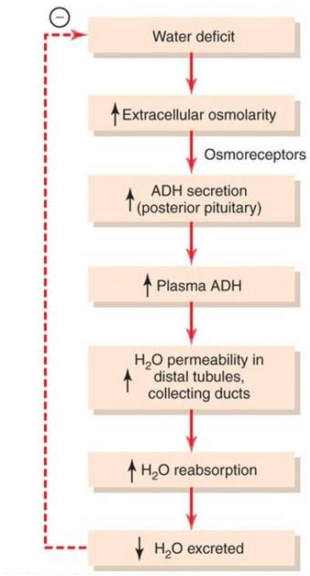


Figure 4: Osmoreceptor ADH feedback system.

2.Thirst mechanism :

A decrease in plasma volume and an increase in the plasma osmolarity causes dehydration, leading to the stimulation of thirst centres located in the hypothalamus. Hypothalamic stimulation occurs when water moves out of thirst centre osmoreceptors by osmosis, causing osmoreceptors to become irritable and depolarize.

3.Role of angiotensin II and aldosterone :

When intake of sodium is decreased, increase in the level of angiotensin II and aldosterone occurs, which helps in reabsorption of sodium by the kidney, hence, preventing large losses of sodium and vice- versa occurs when sodium intake is high[13].

HYPONATREMIA:

Hyponatremia is defined as a serum sodium concentration of less than l35mEq/L[13]. The reported incidences of hyponatremia range from 1% to 4% and are associated with a 7 to 60 fold increase in mortality[14].

Anderson RJ et al (1986) found clinically significant hyponatremia (serum sodium less than l30mEq/L) was a frequent occurrence with incidence 1-2% of hospitalized patients with acute or chronic illness[15].

Wattad A et al in (1992) observed that, out of 11,702 hospital admissions, 161 patients were hyponatremic (serum sodium less than 130 mEq/L), an overall frequency of 1.38%[16].

Many patients do not have symptoms directly attributable to hyponatremia because the level of serum sodium is not severely depressed. Serum sodium concentrations below l20mEq/L are more frequently associated with serious clinical symptoms.

Low plasma sodium in seriously ill patients is a bad sign, whatever the underlying illness[17].

Clinical pathophysiology:

Clinical manifestation of hyponatremia is obvious when serum sodium level falls rapidly below 120mEq/L[14]. Severe hyponatremia (S. Na^+ 110mEq/L or less) can cause fatal brain damage[18].

Central nervous system:

When the serum sodium decreases, plasma osmolality is reduced, water moves into the brain. Cerebral over hydration is the major cause of neurologic manifestation of hyponatremia[14].

The neurologic manifestations are: apathy, anorexia, nausea, vomiting, agitation, headache, altered consciousness, convulsions and coma. Hyponatremia leads to disturbance in the osmotic equilibrium between brain and plasma. Brain adapts to hyponatremia by following mechanisms:

1. Loss of interstitial fluid into the cerebrospinal fluid.
2. Loss of cellular solute, mainly potassium and organic osmolytes.

If the correction of decreased serum sodium concentration occurs more rapidly then increased plasma osmolality may cause dehydration and injure the brain.

Cardiovascular Response:

Cardiovascular response to hyponatremia depends mostly on the effective arterial blood volume, which may be increased, decreased or, normal depending on the underlying disorder.

In a volume-depleted person, hyponatremia induces a further decrement in the intravascular volume by allowing movement of water out of the ECF compartment into the intracellular fluid space. The primary stimulus to the release of ADH is an increase in serum tonicity (osmolality); however, it is also released in response to decrease effective arterial blood volume accompanying hyponatremic edematous

disorders and ECF volume depletion. The ADH potentiates the hyponatremic state by increasing water reabsorption by the renal tubules.

Musculoskeletal:

Muscular cramps and weakness occur, these resolve when serum sodium is corrected.Knochel JP et al found muscular cramp and weakness occurs more commonly in acute hyponatremia than chronic hyponatremia[19].

Renal function:

The usual renal response to hyponatremia is production of dilute urine. But this is impaired by ADH effect.

If urine sodium <10mEq/L, it indicates renal handling of sodium is intact. If urine sodium >20mEq/L it indicates intrinsic renal tubular damage or a natriuretic response to hypervolemia[14].

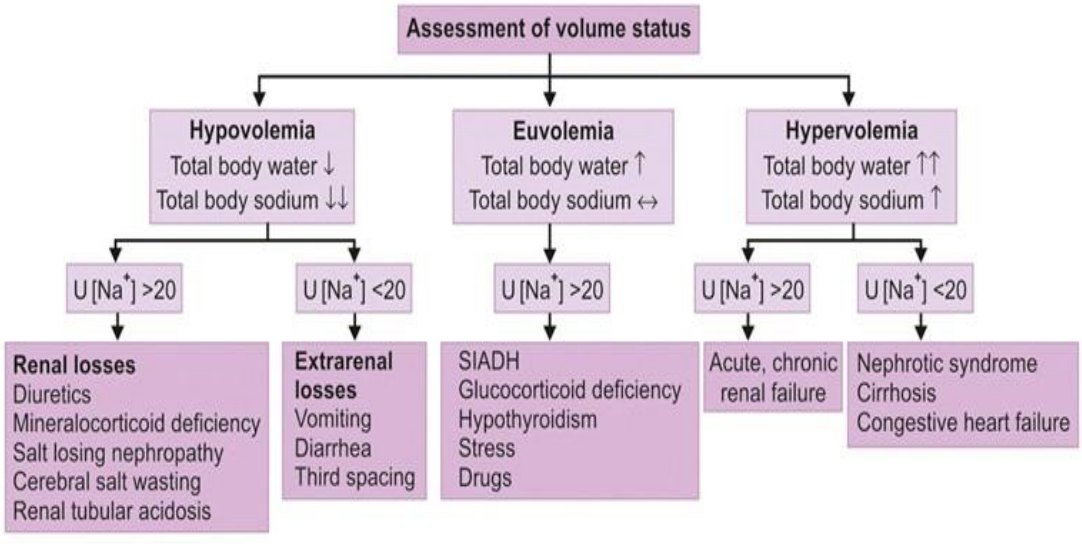


Figure.5 Classification of Hyponatremic States

Sodium in most of the laboratories are measured by flame emission spectro-photometry and report of sodium concentration in mEq per liter of plasma not in mEq per liter of plasma water, so sodium concentration will be artificially low. Ion selective electrode method, which measures sodium activity in plasma water, is not affected by the proportion of serum occupied by lipids and proteins. Plasma osmolality will be normal or isotonic in such conditions[14].

Factitious hyponatremia:

Mainly glucose and mannitol cause this condition. Plasma osmolality in this case is abnormally high. For every 100mg per dl, increase in blood glucose or mannitol concentration, the serum sodium concentration will be lowered by 1.6mEq per litre. The concentration of sodium returns towards normal as the impermeant solute is removed from the plasma[14].

Hypovolemic hyponatremia:

Here conditions are associated with total body sodium depletion and ECF volume contraction owing to losses of sodium in relative excess to water, either through renal or extrarenal routes, or through intracorporealsequestration, often called the third space effect. The most common cause of hypovolemic hyponatremia is viral gastroenteritis causing vomiting and diarrhea[20].

Whattad A et al (1992) had noticed that acute gastroenteritis is the leading cause of hyponatremia, present on admission[16].

Excessive renal loss of sodium is caused by exogenous (drugs) and endogenous (osmotic) diuretics, mineralcorticoids deficiency and certain primary kidney disorders.

Hyponatremia occurring with ECF volume contraction, hyperkalemia and renal sodium wasting without renal failure suggest the possibility of adrenal insufficiency.

Salt wasting sufficient to cause hyponatremia occurs in renal disorders like medullary cystic disease, tubulointerstitial diseases. Gerigk M et al concluded that hyponatremia occurs in young infants in severe acute pyeloneptritis in the absence of obstructive uropathy or vesicouretricreteric reflux. The severe inflammation of the kidney itself causes electrolyte disturbance by transient resistance of the distal tubule to aldosterone[21].

But Meizi ML had outlined that a salt-loosing syndrome with tubular resistance to aldosterone can occur during pyelonephritis in young infants with congenital urinary tract malformation[22].

Euvolemic hyponatremia :

These patients will have normal or near normal total body sodium, despite the presence of hyponatremia. They lack overt signs of water imbalance; specifically they are not edematous. The symptoms are usually, the central nervous system manifestations; urinary sodium concentration is usually greater than 20mEq per liter. Most common cause of euvolemic hyponatremia in children is syndrome of inappropriate anti- diuretic hormone secretion.Guru swamy et al. observed that 64.3%

of children with pneumonia had hyponatremia. Increased secretion of antidiuretic hormone was common with pneumonia[23].

Similarly in a study in PGI Chandigarh, out of 264 children with pneumonia 27% of cases were associated with hyponatremia. Of all the hyponatremia - 68% were secondary to SIADH.

The hospital stay associated with hyponatremia was 60% longer, two-fold increase in complications and 3.5 times higher mortality compared to normonatremicchildren[24].

SIADH:

SIADH is a problem of water retention, not sodium depletion. Aggressivesodium administration is appropriate only to relieve neurologic symptoms.Attempt to correct the hyponatremia with sodium rich solution will cause anincrease in urinary sodium excretion and little change in the serum sodium. Other than treatment of the underlying disease no therapy is indicated to correct the hyponatremia.

Diagnostic Criteria for the Syndrome of Inappropriate ADH release:

1. Hypotonic hyponatremia
2. Absence of hypovolemia or dehydration
3. Absence of edema
4. Normal renal excretory function
5. Normal adrenal, pituitary and thyroid function.
6. Urine osmolality > 100 (usually > plasma)
7. Serum osmolality < 280 and serum sodium < 135
8. Urine sodium > 25
9. Inappropriate antidiuresis

Causes of SIADH:

1. **Tumours:** thymoma, bronchogenic carcinoma, adenocarcinoma of pancreas, hodgkins lymphoma,acute leukemia.
2. **Chest disorders:** pneumonia, positive pressure ventilation**,** atelectasis, pneumothorax, cystic fibrosis, asthma.
3. **CNS disorders:** encephalitis, TB meningitis, bacterial meningitis, trauma, brain tumour, GB syndrome.
4. **Drugs:** diuretics, vincristine, vinblastine, carbamazepine, amitryptaline, morphine, barbiturates.

Acute water intoxication accounts for the diagnosis of hyponatremia in a few, most of whomare hospitalized and receiving intravenous fluid.Arieff Al et al in their study had found the incidence of postoperative hyponatremia among 24412 patients were 0.3% (83 cases). The mortality of those afflicted was 8.4%[25].

Hyponatremia affecting infants less the 3-6 months of age can happen due to dilute administration of formula feeds, plus 1 litre of water, a day[26].

Chronic water intoxication or psychogenic polydipsia leads to hyponatremia which occurs in mentally disturbed patients. Luchins DJ et al studied eight patients with psychogenic polydipsia and found that they had repeated bouts of hyponatremia[27].The mechanisms resulting in hyponatremia in these patients include the washing out of the normal renal medullary concentrating gradient and perhaps an increased sensitivity to ADH.

Hypervolemic hyponatremia :

This includes patients with total body sodium and water in great excess such that they present with pulmonary or peripheral edema. They also have impaired ability to excrete water load, promoting water retention.

These patients may be subcategorized into two groups:

1. The generalized edematous states: congestive heart failure, cirrhosis of liver, and nephrotic syndrome.
2. Advanced acute or chronic renal insufficiency.

Schrier RW et al studied the pathogenesis of sodium are water retention in high output and low output cardiac failure, nephtrotic syndrome, cirrhosis of liver and found that in generalized edematous patients, hyponatremia is due to decreased effective arterial blood volume[28].

Clinical features :

Hyponatremia is symptomatic when serum sodium falls rapidly below120mEq/L[14].

Symptoms:Anorexia, nausea, muscle cramps, lethargy, apathy, disorientation, agitation[29].

Signs: Altered sensorium, decreased tendon reflexes, cheynestokes respiration, hypothermia, pseudobulbar palsy and seizures[29],focal weakness, hemiparesis, ataxia and positive Babinski sign[14].

Gruskin et al studied serum sodium abnormalities in children and found hyponatremia causes shock[30].

Pseudo hyponatremia :

True hyponatremia can be differentiated from pseudohyponatremia by using ion-specific electrode measure. Alternatively, serum water sodium concentration can be calculated from the formula.

$$\frac{100}{Ws} \text{ x observed serum sodium}$$

Where, Ws (water content of the serum) equals 99.1-1.03 LS-0.73Ps. Ls and Ps is the total serum lipid and protein concentrations expressed as gram per deciliter of serum and 99.1 represents the volume of serum minus Crystalloids[31].

Factitious hyponatremia :

Glucose and mannitol increases plasma osmolality. Each 100mg/dl increase in blood glucose or mannitol concentration, serum sodium concentration decreases by 1.6mEq/L[32].

Corrected sodium is:

$$\frac{\text{Serum sodium} + 1.6}{100} \text{ x Blood glucose} - 100$$

MANAGEMENT:

Hyponatremia with contraction of ECF volume, re-expansion with isotonic saline is appropriate therapy: In shock, 20ml/kg isotonic saline can be administered rapidly over 1hr or more as needed and then repeated as necessary until blood pressure and peripheral circulation return to normal.

The number of milliequivalents of sodium necessary to achieve the desired concentration in the patient's blood can be calculated by the following formula[11]

Sodium deficit [mEq] = (DesiredSNa-ActualSNa) xTBW (0.6xweight in kg): Desired Serum Sodium is 130mEq/L, 0.6 is a constant for total body water.

Sarnaik AD et al had stated that treatment of hyponatremic seizures with routine anticonvulsant may be ineffective and is associated with a considerable incidence of apnea. A rapid increase in the serum sodium concentration by 3 to 5 mmol/L with the use of hypertonic saline is safe and efficacious in managing acute symptomatic hyponatremia[33].

Mon SOH et al had recommended that 5-6 mEq/L of increase of serum sodium in 2-3 hr for the patients who presents with convulsion and does not respond to conventional anticonvulsant therapy[34].

Sterns RH outlined that emergency treatment of hyponatremia should be, reserved for a patients who had no time to fully adapt to the disturbances, when the clinical situation demands, treatment can be initiated by infusing 3% saline at 1 to 2ml/kg/hour for 2-3 hours[35].

Rapid correction of hyponatremia that is an increase serum sodium of >2mEq/liter per hour or more than 10-12 mEq/L per day may be dangerous. As this produced potentially fatal neurologic syndrome known as osmotic demyelination syndrome (ODS)[29].

Rapid correction of hyponatremia leads to central pontine myelinosis[36].Demyelinating brain stem lesion manifested as papillary changes,

decerebrateposture and coma. Arieff et al had reported in his studies that brain damage is independent of rate of correction; rapid correction in mildly hyponatremia level is safe. Brain damage is related to magnitude of osmolar change and the presence of hypoxic episode[37].

In the euvolemic patients, water restriction is treatment of choice. For the seriously symptomatic patients with SIADH or acute water intoxication, giving intravenous furosemide followed by intravenous hypertonic saline increases serum sodium concentration.

Hannon RJ et al had reported that in septicemia, hyponatremia and plasma hypoosmolality occurs due to combination of intracellular shift of sodium and water, and dilution of the extracellular space, probably on the basis of physiological antidiuretic hormone (ADH) secretion. Dextrose is potentially dangerous and should be avoided in these circumstances[38].

For hypervolemichyponatremic patients, salt and water restriction is appropriate therapy. Hypertonic saline may be necessary to alleviate symptoms of hyponatremia, but this maneuver is most successful when combined with rigorous water restriction.

Subba Rao SD et al in their study of electrolyte abnormalities in children admitted to pediatric intensive care unit found that out of 305 patients, 29 (9.5%) had hyponatremia, 19 (65.5%) were clinically euvolemic, 8 (27.6%) were hypovolemic, and 2 (6.9%) were hypervolemic. The mortality associated with hyponatremia was (20.7%)[2].

Singhi S et al in their prospective study of 727 sick children found that, the mean duration of hospital stay (7.7 ± 0.4 days) among 217 children with serum sodium ≤ l30mEq/L about 30% longer than that of 510 children with serum sodium concentration (≥ 131 mEq/L) (5.9 ± 0.3 days). The mortality rate in children with normal serum sodium concentration (≥ 131 mEq/L) was 5.3% and the mortality rate was 17% in 47 children with serum sodium <125 mEq/L[39].

Treatment of Hyponatremia[36]:

I. Hyponatremic dehydration:

SecureIV line and restore intravascular volume with 20-40 ml/kg of 0.9% saline or Ringer's Lactate.

A. If symptomatic

Rapidly raise serum sodium by giving 5-6 ml of 3% saline / kg body weight over 10-15 min, if no improvement, then additional 3-4 ml/kg may be given. Further increase serum sodium at a rate of 0.5mEq/L per hour.

B. Asymptomatic child

Give maintenance and replacement therapy with 5% dextrose plus 0.45% saline over 24hours. Increase serum sodium at a rate of 0.5mEq/L per hour.

II. Chronic, asymptomatic hyponatremia :

Underlying cause must be corrected and provide isotonic fluids for replacement and maintenance therapy. Increase in serum sodium >12 mEq/L per day must be avoided.

Table1: Treatment of chronic asymptomatic hyponatremia.

Treatment of Chronic Asymptomatic Hyponatremia				
Treatment	**Mechanism of Action**	**Dose**	**Advantages**	**Limitations**
Fluid restriction	Decreases availability of free water	Variable	Effective and inexpensive; not complicated	Noncompliance
Pharmacologic inhibition of vasopressin action				
Lithium	Inhibits the kidney's response to vasopressin	900–1200 mg/day	Unrestricted water intake	Polyuria, narrow therapeutic range, neurotoxicity
Demeclocycline	Inhibits the kidney's response to vasopressin	300–600 mg twice daily	Effective; unrestricted water intake	Neurotoxicity, polyuria, photosensitivity, nephrotoxicity
V_2 receptor antagonist	Antagonizes vasopressin action		Addresses underlying mechanisms	Limited clinical experience
Increased solute (salt) intake				
With furosemide	Increases free water clearance	Titrate to optimal dose; coadministration of 2–3g NaCl	Effective	Ototoxicity, K^+ depletion
With urea	Osmotic diuresis	30–60 g/day	Effective; unrestricted water intake	Polyuria, unpalatable, gastrointestinal symptoms

HYPERNATREMIA:

Hypernatremia is defined as serum sodium levels >150mEq/L[40]. In one retrospective study by Lindner et al, 981 patients hospitalized in the intensive care unit, 106 had Hypernatremia (9%) 62.2 percent had Hypernatremia on admission, and 7 percent developed the disorder during their hospitalization. Similar findings, particularly with respect to development of Hypernatremia during hospitalization, were noted in another study[41].

Causes of Hypernatremia :

Hypernatremia occurs either by the administration of hypertonic sodium solutions or, much more commonly, by the loss of free water[42, 43] (relative water deficiency).However, salt intake and water loss result in hypernatremia, because the ensuing rise in plasma osmolality stimulates the release of both antidiuretic hormone (ADH) and thirst, thereby minimizing further water loss and increasing water intake. The decrease in water loss and increase in water intake then lower the plasma sodium concentration back to normal.

Hypernatremia is mainly seen in patients who cannot put across thirst normally: children and infants with altered mental status, hospitalized children. Hypernatremia which occurs as a result of water loss is known as dehydration[44]. This differs from hypovolemia in which both water and salt are lost.

UNREPLACED WATER LOSS:

General principles:

The loss of solute-free water, if not replaced, will lead to an increase in the serum sodium concentration. It is vital to recognize that the plasma sodium concentration and plasma osmolality are determined by the ratio between total body solutes (primarily sodium and potassium salts) and the total body water. Thus, it is the sum of the sodium and potassium concentrations that determines the effect that loss of a given amount of fluid will have[45].

SOURCES OF FREE WATER LOSS

A) Insensible and sweat losses: From the skin and respiratory tract occuring by evaporation and sweat are dilute fluids, the loss of which is increased by fever, exercise, and exposure to high temperatures.

B) Gastrointestinal losses: Diarrhoea, vomiting, lactulose will lead to the development of hypernatremia because the concentration of sodium and potassium is less than that of plasma.

C) Central or nephrogenic diabetes insipidus:occurs when the child does not have access to water or he is not able to drink adequate water due to neurological impairment, emesis, anorexia or immature development.

D) Osmotic diuresis: glucose, mannitol, or urea increases the output of urine with a sodium plus potassium concentration that is well below plasma because of the presence of the nonreabsorbed organic solute[46]. Thus, patients with diabetic ketoacidosis and nonketotic hyperglycemia typically present with a high serum osmolality that may not always be accompanied by a high serum sodium concentration because of hyperglycemia-induced water movement out of the cells.

E) Hypothalamic lesions affecting thirst or osmoreceptor function:A failing thirst mechanism with or without associated diabetes insipidus can be seen in children with either congenital or acquired hypothalamic structural lesions.

The best possible therapy of essential hypernatremia is undecided. These children are generally not symptomatic because the hypernatremia is chronic. There is some evidence that chlorpropamide, which increases the renal effect of ADH, may lead to a modest lowering of the plasma sodium concentration[47]. In adding up, a careful neurological and radiological evaluation may demonstrate a treatable disease (such as a benign tumor) that can repair osmoreceptor function.

WATER LOSS INTO CELLS:

Transient hypernatremia i.e., plasma sodium concentration can rise by 10 to 15 mEq/L within a few minutes can be due to severe exercise or seizures, which also lead to the development of lactic acidosis. In this setting, the breakdown of glycogen into smaller, more osmotically active molecules (such as lactate) can increase the cell osmolality, thereby causing the osmotic movement of water into the cells[48]. The plasma sodium concentration returns to normal within 5 to 15 minutes after the end of exertion.

SODIUM OVERLOAD:

Acute and often marked hypernatremia (in which the plasma sodium concentration can exceed 175-200 mEq/L) can be iatrogenic i.e, induced due to the administration of hypertonic sodium-containing solutions. For example: use of sodium bicarbonate for the correction of metabolic acidosis, baking soda for upset stomach[49].

The hypernatremia due to above causes will correct spontaneously if renal function is normal. Too rapid correction should be avoided if the patient is not symptomatic; these patients, however, are less likely to develop cerebral edema during correction, since the hypernatremia is generally very acute with little time for cerebral adaptation. Even with optimal therapy, the mortality rate is extremely high in children with a serum sodium concentration that has acutely risen to >180 mEq/L for reasons that are not well understood. Severe hypernatremia is often better tolerated in young children.

Patients with concurrent renal failure or infants can be treated with peritoneal dialysis. An electrolyte-free hypertonic (8%) dextrose and water solution can initially be used to remove the excess sodium. The high osmolality of the dialysate will minimize water movement from the dialysate into the patient, thereby minimizing further volume expansion.

TREATMENT OF HYPERNATREMIA:

Hypernatremia is mainly due to unreplaced water losses from the gastrointestinal or respiratory tracts or in the urine. Additional factors must be considered in patients with diabetes insipidus (in whom the plasma sodium

concentration is usually near normal and the primary aim of therapy is to decrease the urine output), hypothalamic lesions impairing the thirst mechanism, or primary sodium overload.

WATER DEFICIT:

The water deficit in the hypernatremic patient can be calculated from the following formula, which is derived below[41].

$$\text{Water deficit} = \frac{\text{Plasma } [Na^+] \text{ concentration} - 140}{140} \times \text{TBW}$$

Normally, TBW accounts for about 60% and 50% of lean body weight in younger men and women, respectively.The above formula gives the amount of positive water balance required to return the serum sodium concentration to 140mEq/L. Then, when calculating the amount of free water to be given either intravenously, as dextrose in water, or orally if the patient is able to drink, insensible losses and part of urine and gastrointestinal losses must be added to the calculation.

POTASSIUM:

Body content and physiologic function:

Potassium, the principal cation in ICF, about 150mEq/l.Most of it is present in the muscles. An increase in muscle mass leads to increase in body potassium. Since, most potassium is intracellular, the plasma concentration of does not reflect total body potassium.

Intracellular concentration of potassium approximate 150mEq/L[50] of cell water and the ECF concentration is approximately 4mEq/L (3.5-5mEq/L).This difference in concentration of potassium between ECF and ICF, sustained by the action of Na^+ - K^+ATPase. This pump maintains the high intracellular potassium by pumping out sodium out of the cell and potassium into cells. This chemical gradient is used to maintain the resting membrane potential of the cells.

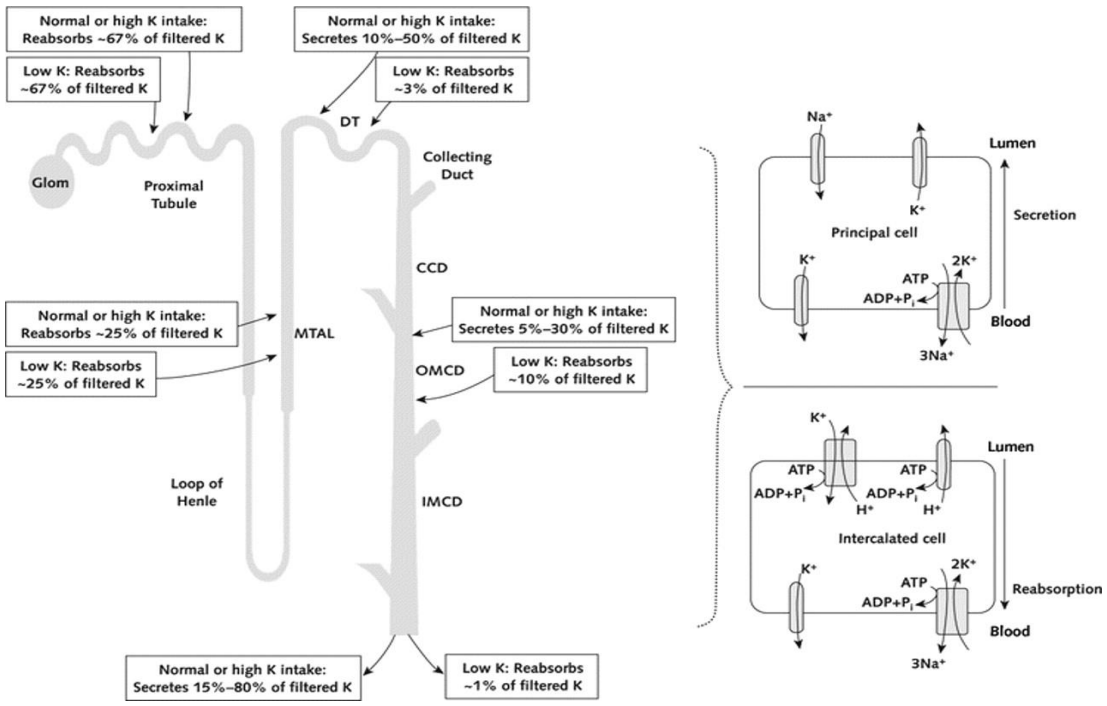


Figure 6: Regulation of Potassium

A daily intake of potassium of l-2mEq/kg body weight (approximately 2 mEq/l00 kCal energy requirment) throughout most of the childhood is recommended. Absorption of potassium is reasonably complete in the upper GIT. More distally, body potassium is exchanged for sodium in the lumen of large bowel. About 98% of potassium is intracellular, particularly in skeletal muscle which provides a large sink to accomodate potassium entering the ECF and helps to maintain serum potassium levels between 3.5 and 5mEq/L. Alterations in the intake of potassium leads to adjustments in excretion, majority of which is by kidneys, followed by bowel and sweat (normal sweat K^+ is 10-25 mEq/L).Extrarenal mechanisms stabilize the ECF K^+ concentration by allowing storage of excess potassium in cells (primarily muscle and liver), until the kidneys can excrete the entire potassium load. Thus factors involved in potassium homoeostasis can be classified into renal and nonrenal factors

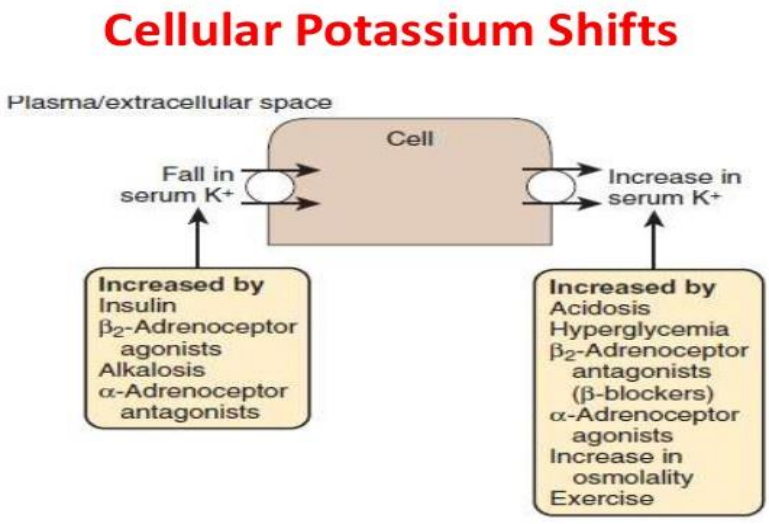


Figure 7: Regulation of extracellular- intracellular potassium shifts (non renal).

1. **Hormonal:**

   a.Insulin can stimulate, the cellular uptake of potassium in muscle (skeletal and cardiac), adipose and hepatic tissues independent of glucose metabolism, thereby lowering plasma potassium.

   b.Catecholamines: Epinephrine stimulate intracellular uptake of potassium, presumably by exerting its cellular effect, by binding to beta 2 adrenergic receptor, stimulating adenylate cyclase, increasing intracellular conversion of ATP to cyclic 3-5 AMP which in turn activates the sodium pump.

   c. Mineralocorticoids: principally aldosterone, appear to exert a significant effect on renal and extrarenal K+ balance. Its primary extrarenal site of action is gastrointestinal tract, although it also affects muscle transport of K^+. In kidney, aldosterone stimulates Na^+ - K^+ ATPase present in the basolateral membrane of epithelial cells and changes the apical or luminal membrane conductance to K^+ allowing for greater K^+ secretion.

2. **Acid - Base Balance:** Acidosis tends to increase and alkalosis decrease serum K+ concentration. For every 0.1 - unit change in blood pH, the plasma K± concentration changes by 0.3 –l.3mEq/L in the opposite direction.

3. **Sodium - Potassium ATPase**

This plays an important function in maintaining the unequal supply of K+ in extracellular and intracellular fluid. Acute impairment of the pump such as with digitalis overdose may cause marked hyperkalemia.

RENAL FACTORS INFLUENCING K+ HOMEOSTASIS:

Chronic K+ balance is primarily regulated by the kidneys, which can adjust the amount of K+ excreted over a wide range (5mEq - 1000rnEq/24 hrs).Normally the rate of K+ excretion in the urine approximates 10-1 5% of that filtered. As the GFR decreases, adaptive tubular processes facilitate K+ excretion and infact tubular secretory mechanisms are primarily responsible for the excretion of K+.

K+ is freely filtered in the glomerulus. Of the filtered load, 60 - 80%[51,52] is reabsorbed in the proximal convoluted tubule with K+ moving through the cells by active transport and between the cells by passive forces[53]; influenced by fluid reabsorption. K^+ appears to be secreted in the thin descending limb of loop of Henle[34], but net reabsorption of about 10% of the filtered load occurs along the thick ascending limb of loop of Henle.The major K^+ secreting segments are the late distal tubule and the cortical collecting duct; where a variety of factors affect the K^+ secreting renal cells.

Potassium may also be reabsorbed in more distal segments such as the medullary collecting duct, in states of K^+ depletion.

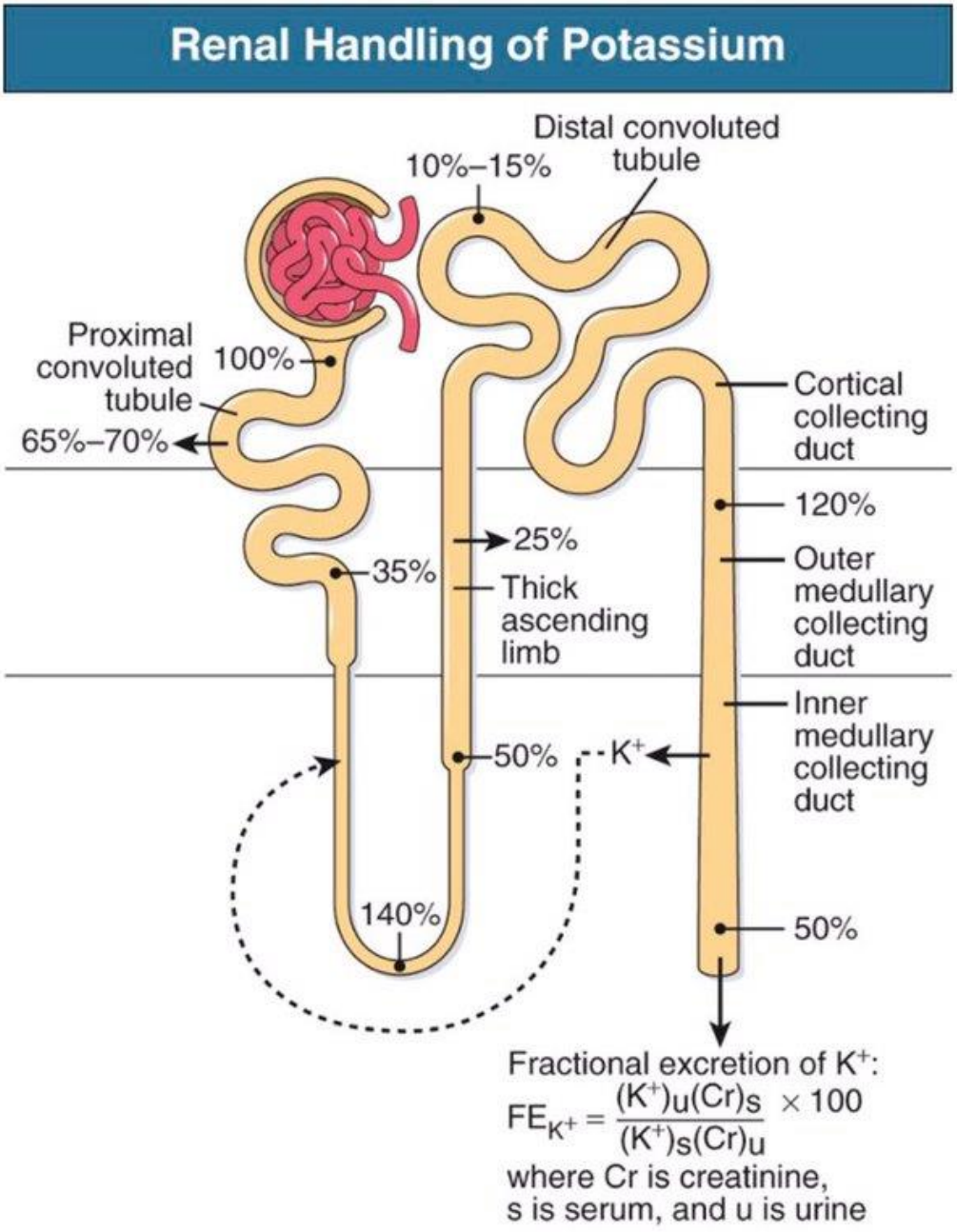


Figure.8 Renal handling of potassium

HYPOKALEMIA:

Hypokalemia is usually defined as a serum potassium concentration <3.5mEq/L.

Etiology:

In general, the causes of hypokalemia can be due to a decreased intake, an excessive loss in the urine, stool or sweat or due to an increased intracellular uptake. Shah GS, Das BK, Kumar S, Singh MK, Bhandari GP* electrolyte disturbances in children with diarrhea , Fifty seven patients aged below 15 years presenting with diarrhoea and dehydration were evaluated for electrolyte and acid base status at admission. The second common abnormality was hypokalemia (46%) which was either isolated (14%) or associated with hyponatremia (26%) [54].

S. Singhi and A. Marudkar, hypokalemia in pediatric intensive care unit, shown that hypokalemia is common among acutely ill children and is associated with a significantly higher mortality. Patients with underlying renal disease, septicemia, bronchial asthma, heart disease with congestive cardiac failure, severe diarrhea, and meningoencephalitis were most likely to show evidence of hypokalemia[55].

S. Singhi S. Gulati S.V.S.S. PrasadFrequency and Significance of Potassium Disturbances in Sick Children study included 727 acutely ill children upto 12 years of age who attended the Pediatric Emergency Services Hypokalemia was found in 101 (13.9%) children, Diarrhea and pneumonia were the commonest underlying diseases associated with hypokalemia[20]

Table 2: Causes of Hypokalemia:

SPURIOUS High white blood cellcount **TRANSCELLULAR SHIFTS** Alkalemia,Insulin β-adrenergic agonists Drugs/toxins (theophylline,barium,toluene) Hypokalemic periodicparalysis **DECREASED INTAKE** anorexia nervosa **EXTRARENAL LOSSES** Diarrhea Laxative abuse Sweating	Distal renal tubular acidosis Proximal RTA Ureterosigmoidostomy Diabetic ketoacidosis Tubulartoxins: amphotericin,cisplatin, aminoglycosides Interstitial nephritis Diuretic phase of acute tubular necrosis Postobstructive diuresis Hypomagnesemia penicillin or penicillin derivatives) Emesis nasogastric suction Chloride losing diarrhea Cystic fibrosis Low chloride formula	Gitelman syndrome Bartter syndrome Renin-secreting tumor 17α-hydroxylase deficiency 11β-hydroxylase deficiency Cushing syndrome 11β-hydroxysteroid dehydrogenase deficiency Liddle syndrome Low urine chloride High urine chloride and normal blood pressure High urine chloride and high blood pressure **RENAL LOSSES** With metabolic acidosis Without specific acid-base disturbance With metabolic alkalosis

Clinical Features of Hypokalemia:

Signs and symptoms of K+ imbalance are more likely seen when the serum K+ drops below 2.5 - 3mEq/L. The rate of change in K+ levels and the magnitude of losses probably affect the severity of symptoms.

Neuromuscular Effects - Decrease in Excitability

1. Muscular effects:

i. Skeletal muscle weakness, respiratory muscle paralysis
ii. Smooth muscle - intestinal ileus, ureteral dilatation.
iii. Cardiac - arrhythmias, ECG changes.
iv. Rhabdomyolysis - myoglobinuria.

2. Neurological effects:

a. General - lethargy, confusion, tetany.
b. Autonomic insufficiency - orthostatic hypotension.
c. Worsening of hepatic encephlopathy.

3. Vascular effects:

a) Acute hypokalemia - vasoconstriction
b) Chronic hypokalemia – vasodilatation

4. Metabolic effects :

a) Hyperglycemia and carbohydrate intolerance.
b) Negative nitrogen balance
c) Decreased secretion of aldosterone, insulin.

Renal effects:

a) Decreased concentrating capacity- polyuria, polydipsia
b) Nephropathy - decreased GFR and renal blood flow
c) Increased renal ammonia production - worsening of hepatic coma
d) Increased bicarbonate reabsorption - maintanance of metabolic alkalosis
e) Sodium retention - edema
f) Decreased Cl- reabsorption - alkalosis

Cardiac effects:

Are serious and include arrhythmias such as premature atrial or ventricular beats, bradycardia, A-V block and possibly ventricular tachycardia or ventricular fibrillation. Patients on digitalis are more sensitive to arrhythmias in the presence of hypokalemia. ECG changes are: flat T waves, depressed ST segment, and appearance of U wave (located between T and P wave).

Treatment :

- Oral K supplements- 2-4mEq/kg/day upto 120-240mEq/day in divided doses.
- IV K supplements for severe hyperkalemia or ongoing K^+ losses-0.5-1.0mEq/kg, given over 1 hour.

When hypokalemia is severe (eg: with ECG changes or severe symptoms), is unresponsive to oral therapy, or occurs in hospitalized patients who are taking digoxin or who have significant heart disease or ongoing losses, K^+ must be replaced IV. Infusion of 40 mEqKCl/hr can be undertaken but only with continuous cardiac monitoring and hourly serum K determinations[54].

When hypokalemia occurs with hypomagnesemia, both the $K^+$and Mg^{2+} deficiencies must be corrected to stop ongoing renal K wasting.

Hyperkalemia:

Defined as serum potassium levels >5.5mEq/L (normal value of serum K+ levels vary with age). Because the kidney has a large capacity to excrete excess potassium and to prevent hyperkalemia, this electrolyte abnormality is most often seen when renal excretory mechanisms are impaired.

B Paice, J M Gray, D McBride, T Donnelly, and D H Lawson study showed Significant hyperkalaemia occurred in 406 out of 29 063 patients admitted to a major Scottish teaching hospital in one year (1.4%). Mortality was higher in these patients than in control patients and was strongly correlated with the severity of the hyperkalaemia. Overall seven deaths were directly due to hyperkalaemia (out of 58 deaths among patients with hyperkalaemia). Factors contributing to a poor prognosis were severity and speed of onset of hyperkalaemia and the presence of appreciable renal impairment[55].

Hyperkalemia, it is frequently "a silent and a potential life threatening electrolyte imbalance" among patients with ESRD under maintenance hemodialysis. The prevalence of hyperkalemia in HD patients was reported to be about 8.7-10%. Mortality related to hyperkalemia has been shown to be about 2-5% of deaths among patients with ESRD) and about 24% of patients with HD required emergency hemodialysis due to severe hyperkalemia[56].

Etiology:

TABLE 3: Causes of hyperkalemia:

SPURIOUS LABORATORY VALUE Hemolysis Tissue ischemia during blood drawing Thrombocytosis Leukocytosis INCREASED INTAKE Intravenous or oral Blood transfusions TRANSCELLULAR SHIFTS Acidemia Tumor lysis syndrome Tissue necrosis Hemolysis/hematomas/GI bleeding Digitalis intoxication Beta-adrenergic blockers	Exercise Hyperosmolality Insulin deficiency Malignant hyperthermia Hyperkalemic periodic paralysis Acquired Addison disease DECREASED EXCRETION Renal failure Primary adrenal disease 21-hydroxylase deficiency 3β-hydroxysteroid dehydrogenase deficiency Lipoid congenital adrenal hyperplasia Adrenoleukodystrophy Hyporeninemic hypoaldosteronism Urinary tract obstruction Sickle cell disease Kidney transplant Lupus nephritis	Renal tubular disorders drugs Angiotensin-converting enzyme inhibitors Angiotensin II blockers Potassium-sparing diuretics heparin

SPURIOUS HYPERKALEMIA:

This occurs most commonly in children because of the difficulties in obtaining the blood samples. This is caused by hemolysis which occurs during heel stick or phlebotomy, prolonged tourniquet application or fist clenching, which leads to release of potassium from the muscles.

Serum potassium will be 0.4mEq/l more than plasma value. This is exaggerated with thrombocytosis due to the release of potassium from the platelets. Increase in WBC counts can cause a increase in the serum potassium concentration. Correction factors have been discussed but ultimately blood has to be drawn again[57].

Clinical features:

Hyperkalemia reduces transmembrane potential toward threshold levels, producing delayed depolarisation, faster repolarisation and a slower conduction velocity. Paresthesias are followed by weakness and eventually flaccid paralysis if emergency treatment is not instituted. Hypocalcemia, hyponatremia and acidosis exacerbate the dangerous effects of hyperkalemia. The earliest ECG abnormality seen in hyperkalemia is a tall peaked symmetric Twave with a narrow base, the so called tented T wave. A progressive increase in the serum K+ levels produces the following ECG changes- ST segment depression, increased PR interval, flattening of P wave, widening of QRS complex.

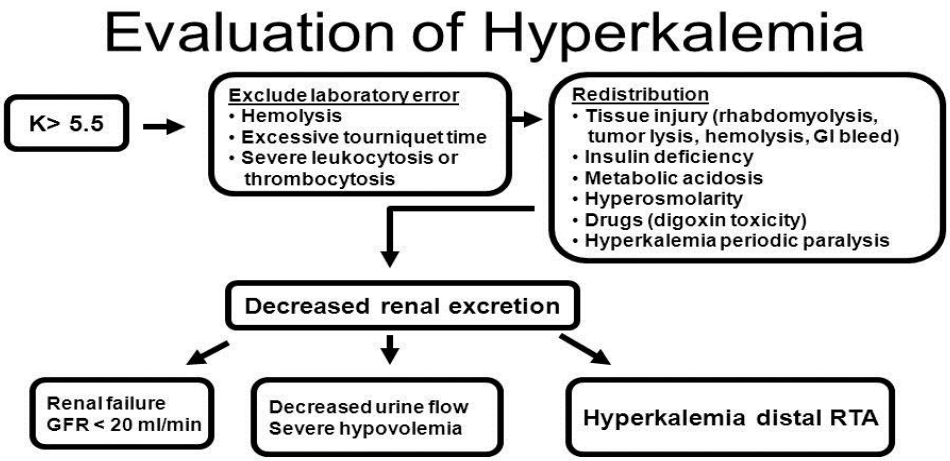


Figure 9 Evaluation of hyperkalemia

Treatment:

Therapeutic approach depends on serum potassium level, ECG and the risk of the problem worsening due to hyperkalemia.

Vigorous treatment is needed when serum potassium values are high and there are ECG changes. Main step is to stop all sources of additional potassium i.e., oral or intravenous. Washed red blood cells may be used when blood transfusion is required. When the serum potassium is >6.5mEq/l, an ECG must be taken immediately. Peak T wavesare the first sign of hyperkalemia followed by prolonged PR interval and in severe cases prolonged QRS complex.

Treatment goals are:

1. To stabilize the heart in order to prevent arrhythmias.
2. Removal of excess potassium from the body.

Treatment to prevent arrhythmias – calcium gluconate, calcium stabilizes the cell membrane of heart cells. But they do not remove potassium from the body. Given through intravenous route over a few minutes, acts immediately.

Bicarbonate causes intracellular movement of potassium, thus helps in lowering potassium value.

Insulin leads to intracellular movement of potassium, and it must be given along with glucose to prevent hypoglycaemia. This works in 30 minutes.

Nebulisation with salbutamol leads to rapid intracellular movement of potassium[58].

A loop diuretic helps in excretion of potassium, hence can be used when there is no anuria.sodium polystyrene sulfonate can also be used either rectally or orally, sodium in the resin is exchanged with potassium.

For acute removal of potassium dialysis may be needed: hemodialysis rapidly lowers serum potassium levels. Peritoneal dialysis is not as quick as hemodialysis.

Long term management includes decreasing the intake of potassium in the diet, eliminating or decreasing the use of drugs causing hyperkalemia.

CALCIUM

Physiology:

98% of body calcium is in the skeleton which is in equilibrium with the extracellular concentration of calcium[6]. Serum concentration of calcium is a poor reflection of total body stores. Approximately 1 to 2% of body calcium exists in the ECF for physiological functions like blood coagulation, cellular communication, exocytosis, endocytosis, muscle contraction and neuromuscular transmission. Calcium affects the intracellular processes, through its calcium- binding regulatory protein, calmodulin.

Calcium exists as three forms in the plasma[5]: ionic calcium(48%), that is physiologically active component, albumin bound(40%) and complexed withother anions [phosphate, sulphate, lactate, citrate and bicarbonate(12%)]. As a consequence, low serum albumin levels lower total calcium without altering the ionized component whereas, alkalosis and infusion of anions(citrate, in massive blood transfusions) decrease the ionized component by increasing the complexed component. Calcium stores depend on dietary calcium intake, absorption from the gastrointestinal tract and renal excretion. Corrected calcium can be calculated using the formula:

Corrected Ca=[4- plasma albumin in g/dl]*0.8+measured serum calcium.

Most of the calcium which is filtered is reabsorbed in the proximal tubule(70%), ascending loop of Henle(20%), and the distal convoluted tubule and collecting duct(5-10%). Parathormone, calcitonin, vitamin D, thiazide diurectics and volume depletion promote calcium reabsorption. Volume expansion, increased sodium intake, diuretics such as mannitol and frusemide promote calcium excretion.

The intestines serve as a long term homeostatic mechanism for calcium. Although the major source of calcium is dietary, less than 15% of dietary calcium is absorbed, primarily in the ileum and jejunum by means of active transport and facilitated diffusion. Calcium is controlled primarily by major regulatory hormones, PTH, calcitonin, vitamin D.

REGULATION OF PLASMA CALCIUM:

Cutaneous synthesis of vitamin D occurs by conversion of 7-dehydrocholesterol Cholecalciferol on exposure to UV light. 25- hydroxylation occurs in the liver, is thought to be non rate limiting, and is widely accepted as a summary measure of vitamin D stores. Further hydroxylation to 1,25- dihydroxy vitamin D(calcitriol) occurs predominantly in kidney, but also occurs in non-renal tissues.

Increased calcium absorption is required in puberty; hence, synthesis of calcitriol is increased during puberty. Intestinal calcium absorption is also increased in Vitamin D excess.

The net balance between calcium entry and exit fluxes occurs during skeletal growth in children.The kidneys play a major role in the regulation. Kidney uses a system of filtration and reabsorption. In the proximal tubule, most of the calcium is reabsorbed by convective flow(as for sodium and water); in the distal segments of the tubule the transport mechanisms are more complex. **Calcium sensing receptor** is a G protein coupled receptor, which allows the parathyroid chief cells, the thyroidal C cells and the ascending limb of the loop of Henle to respond to the changes in the extracellular calcium concentration. The ability of the CaSR to sense the serum calcium concentration is essential for the appropriate regulation of OTH secretion by the parathyroid glands and for the regulation of passive paracellular

calciumabsorption in the loop of Henle. Decrease in extracellular calcium concentrations, stimulates the CaSR in parathyroid glands, resulting in an increase in PTH secretion. PTH increases distal renal tubular reabsorption of calcium within minutes and stimulates osteoclast activity, with release of calcium from the skeleton within 1-2 hour.

HYPOCALCEMIA:

Hypocalcemia is total serum calcium concentration less than 9mg/dl.

Etiology:

1. **Elevated PTH level**
    a) Vitamin D deficiency
    b) Vitamin D dependent rickets
    c) Chronic kidney disease
    d) Pseudohypoparathyroidism
2. **Decreased PTH level**
    a) Dysgenesis of parathyroid gland
    b) DiGeorge syndrome(22q11 deletion)
    c) Autoimmune destruction of parathyroid gland
3. **Calcium sensing receptor activating mutation**
    a) Autosomal dominant hypocalcemia
4. **Tissue consumption of calcium**
    a) Acute pancreatitis
    b) Osteoblastic bone metastasis
    c) Hungry bone syndrome(post parathyroidectomy)
    d) Hyperphosphatemia

Symptoms:

Acute

1. Paresthesia of lips, extremities(fingers, toes)
2. Tetany, seizures
3. Laryngeal stridor, apnea in neonates
4. Congestive cardiac failure, arrhythmias
5. ECG-prolonged QT interval, heart block

Chronic:

1.Candidiasis, subcapsular cataracts, basal ganglia calcification, extrapyramidal symptoms, enamel hypoplasia, papilledema

2.Features of rickets

3. Round facies, short stature and a short neck with short metacarpals and metatarsals.

Latent signs

1. Chvostek sign: lateral cheek is tapped with forefinger, 0.5-1.0 cm below the zygomatic process and 2cm anterior to the tragus. Positive sign is twitching of the corner of mouth due to contraction of circum oral muscles.
2. Trosseau sign: Sphygmomanometer cuff is inflated above systolic pressure for 3 minutes. Positive sign is flexion of wrist and metacarpophalangeal joints, extension of interphalangeal joints and adduction of fingers.

Nicholas MD Bart C Michael AS Samuel RN David T found that out of the 145 critically children, 71 had low serum calcium values. Out of 71, 26 had ionized hypocalcemia. Death occurred in 8 of 26 cases who had ionized hypocalcemia[59].

Gerardo JS et al showed that, out of the 15 cases admitted in PICU the blood ionized calcium level was 4.45+/-0.06mg/dl on admission, rose significantly on days2 and 3, and was 5.12+/-0.04mg/dl at discharge ($p<0.005$)[60].

A study by Gauthier, Bernard MB, et al showed that out of the 45 critically ill children 6patients were hypocalcemic. Five hypocalcemic patients were studied and was found to have higher calcitonin levels and higher PTH levels[61].

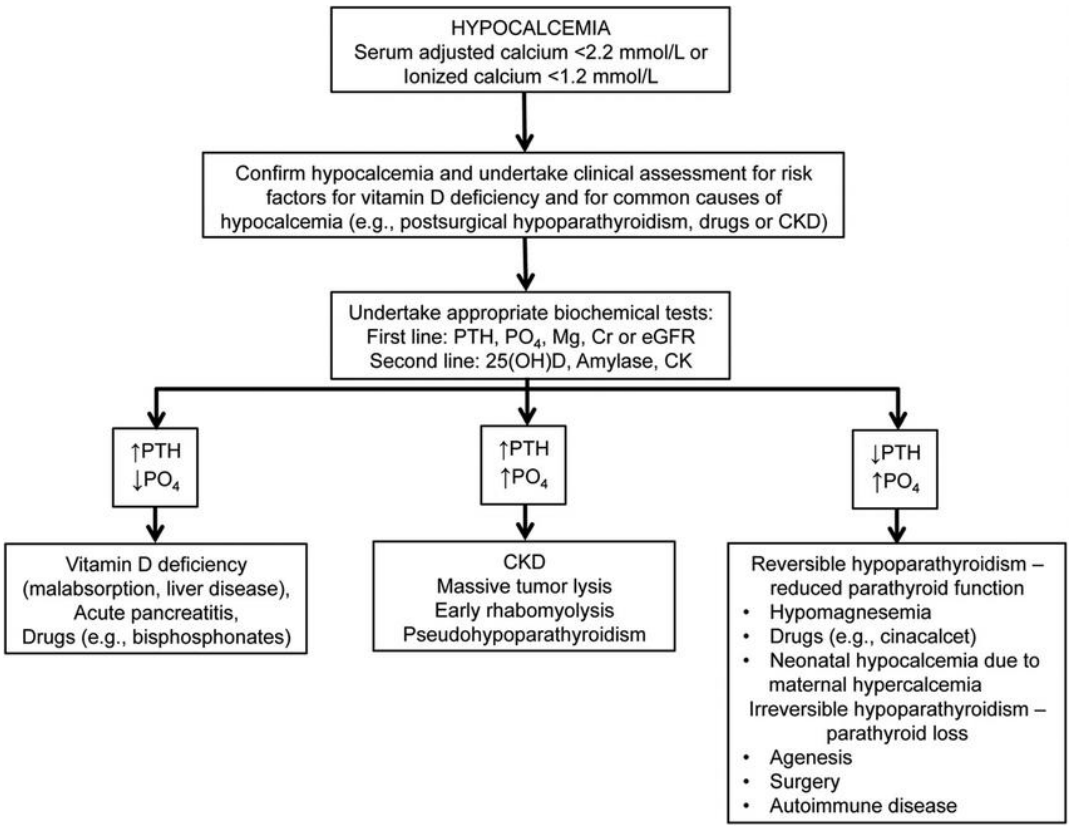


Figure 10:Evaluation of hypocalcemia.

Management:

Symptomatic hypocalcemia requires administration of IV calcium gluconate 10% (1 to 2 ml/kg), diluted to twice the volume in dextrose[6]. The infusion should be given over 10 to 15minutes with cardiac monitoring. Effects of the acute infusion are transient; the same dose is repeated q 6-8 hour till symptoms resolve and maintenance infusion or oral calcium therapy is necessary. Oral supplementation requires 50 to 75 mg/kg/day of elemental calcium given 3 to 4 times a day. Oral calcium should be administered between meals to minimize binding to dietary phosphate.

The underlying cause requires recognition and management. Concomitant hypomagnesemia should be treated with magnesium sulphate IV. In the presence of acidosis, calcium levels should be corrected first since correction of acidosis would further deplete ionized calcium.

HYPERCALCEMIA:

Hypercalcemia is defined as a serum calcium concentration exceeding 10.5mg/dl[5]. Factitious hypercalcemia can occur if a tourniquet is applied for a prolonged time prior to drawing blood as extravasation of fluid from the venous compartment leads to an increase in concentration of albumin and of albumin bound calcium. If obtaining an accurate serum calcium level is critical, the sample should be drawn from a free flowing vessel or after application of a tourniquet for as little time as possible.

Causes of hypercalcemia:

1. **Increased PTH levels**
    a) Parathyroid adenoma: isolated or in multiple endocrine neoplasia syndrome
    b) Inactivating mutations of calcium sensing receptor
    c) Chronic kidney disease

2. **Excessive vitamin D effect**
    a) Vitamin D overdose
    b) Sarcoidosis, tuberculosis, Hodgkins lymphoma
    c) Idiopathic hypercalcemia of infancy
    d) William syndrome: A ugmented recruitment of vitamin D receptor
    e) Hypophosphatasia: Increased synthesis of calcitriol.

3. **Increased bone resorption/ reduced calcium incorporation**
    a) Humoral hypercalcemia of malignancy
    b) Jansen metaphyseal dysplasia: Activating mutation of PTH/PTHrp receptor
    c) Vitamin A overdose
    d) Prolonged immobilization
    e) Adynamic bone disease(with calcium and calcitriol supplementation)

4. **Thiazide diuretics**

CLINICAL FEATURES:

1. Lethargy, confusion, depression, coma
2. Hyporeflexia
3. Muscle weakness
4. Constipation
5. Bradycardia, systemic hypertension
6. Headache
7. Nephrocalcinosis, nephrolithiasis
8. Polyuria
9. Reduced QTc interval

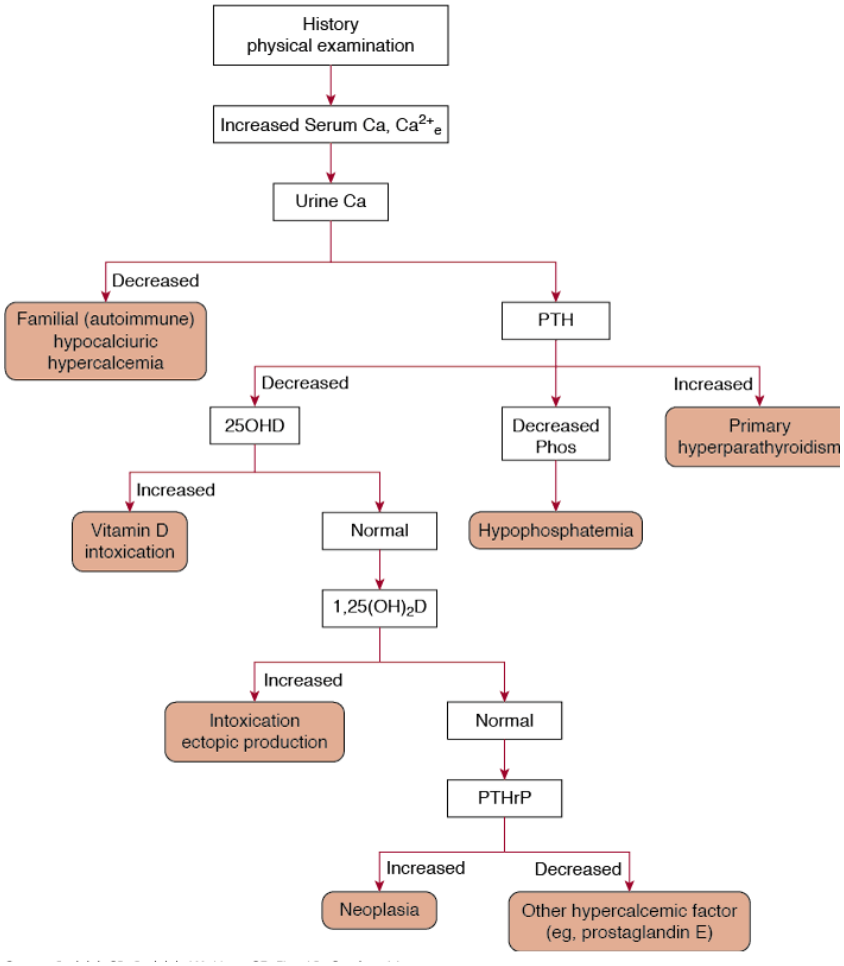


Figure 11: Diagnostic approach to hypercalcemia.

MANAGEMENT:

Hypercalcemia is often accompanied with dehydration.

For mild hypercalcemia(<12mg/dl) in asymptomatic children avoiding dehydration and reducing dietary calcium is sufficient[5].

Moderate hypercalcemia(12-14mg/dl), aggressive rehydration with IV saline is instituted at 1.5 to 2 times maintenance rate, which decreases the renal sodium dependent calcium reabsorption . Hypokalemia and hypomagnesemia should be monitored.

Rapid correction of hypercalcemia is necessary in symptomatic patients or those with severe hypercalcemia(>14mg/dl). In addition to IV hydration followed by furosemide, administration of bisphosphonates and calcitonin should be considered. Bisphosphonates block osteoclastic activity within 2 to 4 days following intravenous administration. Pamidronate(0.5-1mg/kg/dose) is given at a concentration of 10mg/100ml as a infusion over 4 hours for 3 consecutive days.Repeat infusions may be required every 1 to 3 months depending on the degree of hypercalcemia.

Intramuscular or subcutaneous calcitonin at 4 to 8IU/kg q 12 hour has a rapid short lasting effect due to development of tachyphylaxis over 24-48 hours. Therefore it is administered in combination with bisphosphonates.

Hydrocortisone (1mg/kg/dose q 6hour) is beneficial in vitamin D intoxication, granulomatous disease or paraneoplastic syndrome. Primary hyperparathyroidism requires surgical intervention i.e, subtotal or total parathyroidectomy with autotransplantation.

Children with chronic kidney disease and secondary hyperparathyroidism require necessary interventions to decrease PTH secretion with calcimimetics, low calcemic vitamin D analogs and parathyroidectomy. Subtotal or total parathyroidectomy is indicated when serum PTH level are more than 800pg/ml.

CHLORIDE:

It is the principal anion in the extracellular space. It helps in maintaining the cellular integrity and acid-base balance.

It moves in and out of the cells with sodium and potassium and combines with major cations to form sodium chloride, hydrochloric acid, potassium chloride. High levels of chloride are found in cerebrospinal fluid, but it can also be found in bile, in gastric, pancreatic juices. Serum chloride levels normally range between 96 and 106 mEq/l[62].

MAINTAINING CHLORIDE BALANCE:

Chloride reabsorption follows sodium reabsorption. 1litre of filtrate of kidney tubules contains around 140mEq of sodium. Sixty five to seventy percent of the total amount of filtered chloride is reabsorbed. Chloride is mainly transported via electroneutral cation –Cl cotransporters, which permit Chloride to always follow Na and K across cellular membranes.

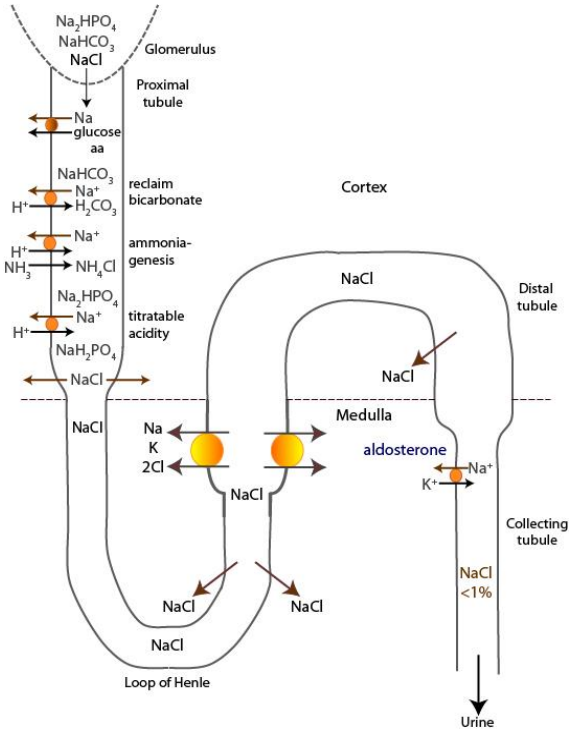


Figure.12 Chloride balances in renal tubules

The kidneys play a role in the maintenance of total chloride balance[62].Both active and passive transport processes help in the reabsorption of chloride by the nephrons of the kidney. The proximal tubule is responsible for reabsorbing the majority of the filtered chloride, and the ascending loop of Henle reabsorbs another significant amount. The distal tubule and collecting duct, although reabsorbing a smaller quantity of chloride, may also play an important role in this balance. The quantity of chloride excreted into the urine is not constant, but varies from day to day depending on whether the kidneys are trying to conserve or eliminate chloride. This ability of the kidneys to vary daily chloride excretion keeps total body chloride values relatively constant and maintains serum chloride concentrations within a narrow range despite marked daily variations in chloride intake.

Hypochloremia:

CAUSES:

1. Extrarenalcauses include

a) Decreased intake of sodium chloride
b) Gastrointestinal losses (e.g., vomiting and nasogastric suction associated with loss of HCl, or diarrhea as a result of abnormalities in small bowel transport)
c) Loss of fluids through the skin(e.g., burns).

2. Renal causes of chloride (and sodium) losses are:

a) Diuretic abuse (loop diuretics);
b) Osmotic diuresis (e.g., mannitol, diabetic ketoacidosis, or hyperosmolar nonketotic coma);
c) Renal diseases associated with a salt-losing nephropathy including interstitial nephritis; chronic renal failure; and conditions associated with adrenal insufficiency (e.g.. lack of endogeneous or exogeneous glucocorticoids or mineralocorticoids).

Another finding often associated with total chloride depletion is metabolic alkalosis (blood pH greater than 7.45). The reabsorption of sodium bicarbonate ($NaHCO_3$) in the proximal and distal tubule is increased because total body chloride depletion results in both ECF volume contraction (which stimulates HCO_3 reabsorption) and decreased quantities of filtered chloride available to the tubules for reabsorption with sodium. The virtual absence of chloride in the urine in the presence of a metabolic alkalosis is a strong indication that total body chloride depletion is present.

Clinical conditions associated with excess water retention can cause a dilutional hyponatremia with a proportionate decrease in the chloride concentration. This form of hypochloremia does not reflect total body chloride or sodium depletion, and, in fact, many of the conditions associated with dilutional hypochloremia have a normal or increased total body content of chloride and sodium.

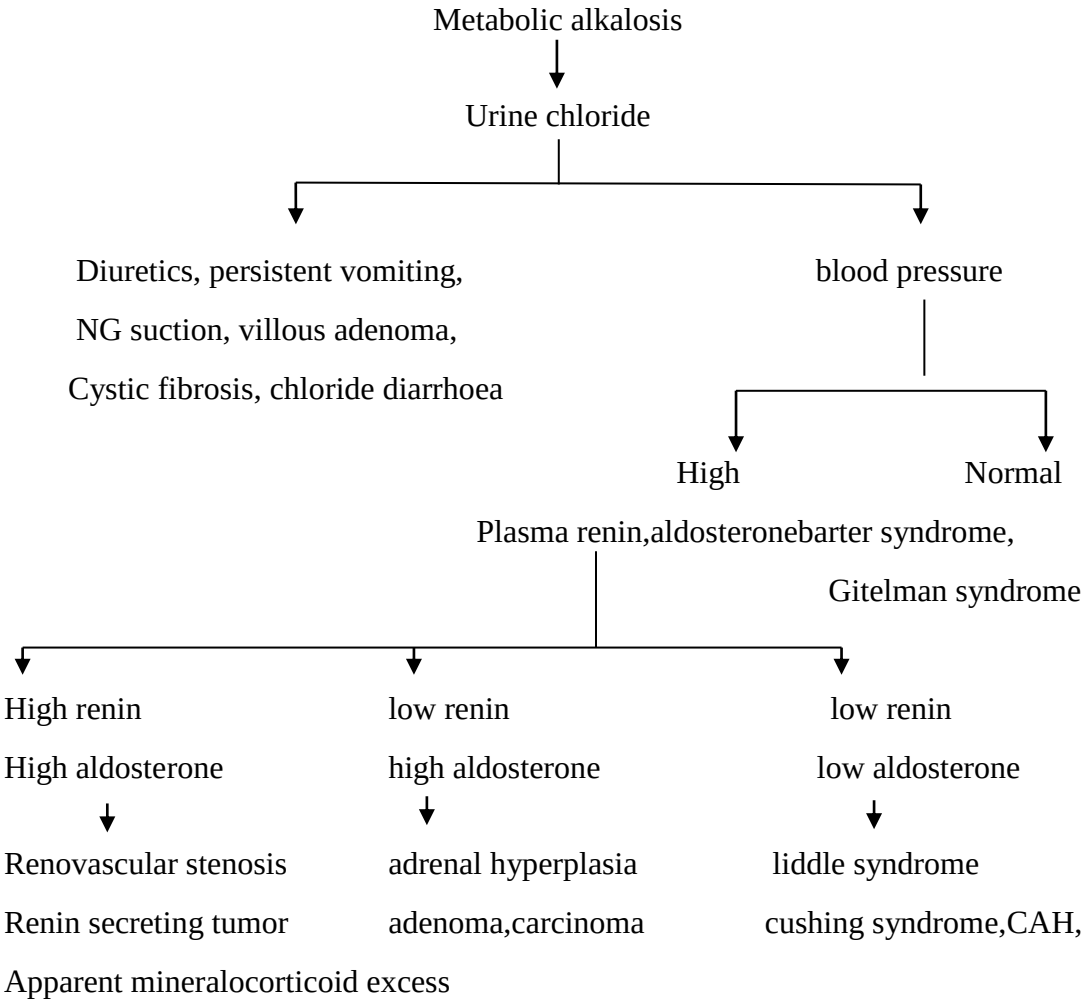


Figure.13 Approach for hypochloremia.

MANAGEMENT:

Treatment for hypochloremia focuses on correcting the underlying cause. Chloride may be replaced through fluid replacement or through drug therapy.

Treatment of chloride responsive states includes volume repletion and correction of chloride and potassium deficits[62]. Normal saline with added potassium chloride is the fluid of choice. Proton pump inhibitors minimize gastric acid loss in patients with continuous gastric drainage. Patients with metabolic alkalosis associated with the use of loop diuretics may need supplemental potassium chloride or therapy with a potassium sparing diuretic. In primary hyperaldosteronism, treatment with spironolactone or amiloride is useful. Management of potassium losing tubulopathies includes fluid replacement, potassium chloride supplementation, and therapy with indomethacin or ibuprofen. Acetazolamide may be used in patients with chloride resistant metabolic alkalosis with normal renal function.

Hyperchloremia:

CAUSES:

1. **Pure water loss**

   Skin losses- fever, hypermetabolic states

   Inadequate water intake- loss of thirst perception

   Renal losses- Central diabetes insipidus, nephrogenic diabetes insipidus.

2. **Loss of hypotonic fluids**

   Extrarenal- diarrhoea, burns.

   Renal losses- diuretics, osmotic diuresis,

3. **Sodium gain**

   Administration of 3 to 5% NaCl, salt water drowning

4. **Hyperchloremic metabolic acidosis**

   Renal tubular acidosis

   Early renal failure

   Recovery from diabetic ketoacidosis[63].

Study by O'Dell Tibby SM Durward A Murdoch IA showed that hyperchloremia is the dominant cause of metabolic acidosis in the post resuscitation phase of pediatric meningococcal sepsis[63].

A study by Bandarn S et al showed that of the 240 cases included in the study, 98 had hyperchloremia and the incidence of acute kidney injury was high in hyperchloremia group in severe sepsis cases[64].

MANAGEMENT:

Treatment of GI causes of hyperchloremic acidosis includes

1. Administration of saline solutions to repair the volume losses and
2. Administration of potassium

Patients with chronic acidosis secondary to diarrhoea benefit from long term therapy with sodium and potassium citrate solutions.

Once the underlying cause has been identified specific therapy is needed to control the primary problem. Depending on the type of RTA, the goals of therapy are to decrease the rate of progressive renal insufficiency by preventing nephrocalcinosis and nephrolithiasis; to neutralize metabolic bone disease; and, in children, to improve growth.

Blood Glucose:

Glucose plays a principal role in providing fuel and is a source of energy storage in the form of glycogen, fat and protein[65].

Normal levels of blood glucose are maintained by dietary intake, gluconeogenesis, and glycogenolysis of glycogen maintains normal blood glucose levels.

Dietary sources of glucose are by ingestion of polysaccharides, mainly starch and disaccharides, including lactose, maltose, and sucrose.

The break-down of hepatic glycogen provides the rapid release of glucose, which maintains a constant blood glucose concentration.

Glucose is essential for energy metabolism in the brain where its utilization accounts for nearly all of the brains oxygen consumption.Cerebral transport of glucose is a Glut1, carrier mediated, facilitated diffusion process that is dependent on blood glucose concentration[65].

SYSTEMIC GLUCOSE BALANCE:

Normally, the rates of endogenous glucose influx into the circulation nd those of glucose efflux out of the circulation into tissues other than brain are co-ordinately regulated- largely by the plasma glucose- lowering(regulatory) hormone insulin and plasma glucose- raising(counterregulatory) hormones glucagon and epinephrine- such that systemic glucose balance is maintained, hypoglycaemia (as well as hyperglycemia) is prevented, and a continuous supply of glucose to the brain is ensured. This is accomplished despite wide variations in exogenous glucose influx (eg. after meals versus fasting) and in glucose efflux(eg., during exercise versus rest).

Gluconeogenesis and glycogenolysis are important for maintenance of the plasma glucose concentration.

Systemic Glucose Balance and Effects of Circulating Hormones on Endogenous Production and Use of Glucose

Source of Glucose Influx or Efflux	Hormonal Effects		
	Insulin	Glucagon	Epinephrine
Glucose Influx Into the Circulation			
Exogenous glucose delivery			
Endogenous glucose delivery			
In liver: glycogenolysis and gluconeogenesis	↓	↑	↑
In kidneys: gluconeogenesis	↓		↑
Glucose Efflux out of the Circulation			
Ongoing brain glucose utilization			
Variable glucose utilization by other tissues (e.g., muscle fat, liver, kidneys)	↑		↓

*Total glucose influx = total glucose efflux.

Figure 14: Systemic glucose balance and effects of circulating hormones on glucose production.

HYPOGLYCEMIA:

A whole blood glucose concentration of <55mg/dl (10-15% higher for serum or plasma) represents hypoglycaemia in infants and older children, as the counter regulatory mechanisms are activated at these glucose concentrations[65].

An alternative definition of hypoglycaemia is a decrease in the blood glucose level or its tissue utilization that results in demonstrable signs or symptoms. These signs and symptoms usually include altered mental status and/ or sympathetic nervous system stimulation. The glucose level at which an individual becomes symptomatic is highly variable.

Koh TH, Aynsley G measured measured sensory evoked potentials in relation to blood glucose concentration. Out of the 17 children: 13 were fasted or given insulin to investigate endocrine or metabolic and 4 had spontaneous episodes of hypoglycaemia. Abnormal evoked potentials were recorded in 10 of the 11 children whose blood glucose fell below 2.6mmol/L. Their findings suggest that blood glucose concentration should be maintained above 2-6mmol/L to ensure normal neural function[66].

Davis (1997) suggested that a child's irregular eating habits, sporadic physically active nature, and potential inability to identify signs of hypoglycemic onset, can lead to higher frequencies of hypoglycemia. Finally, an abstract has detailed preliminary evidence that onset of HAAF may occur quicker in children than in adults (Caplin et al., 2000), exacerbating the risk of severe hypoglycemia[67].

SIGNIFICANCE AND SEQUELAE:

On the whole the intrinsic hepatic glucose production in infants and young children can be accounted for by brain metabolism. Since brain grows rapidly in the 1st year of life, sustained or repetitive hypoglycaemia can retard brain development and function[67].

In rapidly growing brain, glucose helps in protein synthesis and myelination which help in normal brain maturation.

Under conditions of severe and sustained hypoglycemiaa, cerebral structural substrates may become degraded to energy- usable intermediates such as lactate, pyruvate, amino acids, and ketoacids, which can support brain metabolism at the expense of brain growth. Although the brain may metabolize ketones, these alternate fuels cannot completely replace glucose as an essential CNS fuel. The major long

term sequel of severe, prolonged hypoglycaemia is cognitive impairment, recurrent seizure activity, cerebral palsy and autonomic dysregulation. Permanent neurologic sequel are present in 25-50% of patients with severe recurrent symptomatic hypoglycaemia who are younger than 6mo of age and include reduced myelination in cerebral white matter and atrophy of cerebral cortex, reflected in enlargement of the sulci and thinning of the gyri of the brain.

The most feared, and perhaps most common (Kaufmann, 1998; Pocecco and Rofani, 1998), symptom of severe hypoglycemia is seizure generation[68]. Seizures induced by hypoglycemia have been described as showing ictal spike and wave activity and are believed to be generalized in origin (Velísek et al., 2008; Pitkänen et al., 2005)[69]

Table.4 Clinical manifestations of Hypoglycemia:

Sympathetic Nervous System	*Central Nervous System: Neuroglycopenia*
Sweating	Cognitive impairment, confusion
Palpitations	Behavioral changes
Tremor	Weakness
Hunger	Paresthesias
Arousal/Anxiety	Lack of motor coordination
Pallor	Slurred speech
	Visual disturbances
	Vertigo
	Focal neurological deficits
	Seizures
	Coma and Death

CLASSIFICATION OF HYPOGLYCEMIA IN INFANTS AND CHILDREN[65]:

1. NEONATAL, INFANTILE, OR CHILDHOOD PERSISTENT HYPOGLYCEMIAS

a. Hyperinsulinism

- Recessive K_{ATP}channel HI
- Recessive HADH(hydroxyl acyl-coA dehydrogenase)
- Recessive UCP2(mitochondrial uncoupling protein 2)
- Focal K_{ATP} channel HI
- Dominant K_{ATP} channel HI
- Acquired islet cell adenoma
- Beckwith weidmann syndrome
- Insulin administration(Munchausen syndrome by proxy)
- Oral sulfonylurea drugs
- Congenital disorders of glycosylation

b. Counterregulatory hormone deficiency

- Panhypopituitarism
- Isolated growth hormone defieciency
- Adrenocorticotropic hormone deficiency
- Addison disease
- Epinephrine deficiency.

c. **Glycogenolysis and gluconeogenesis disorders**

- Glucose-6-phosphatase deficiency
- Liver phosphorylase deficiency
- Phosphorylase kinase deficiency
- Glycogen synthetase deficiency
- Galactosemia

- Hereditary fructose intolerance

d. **Fatty acid oxidation defects**

- Carnitine transporter deficiency
- Carnitine translocase deficiency
- Secondary carnitine deficiencies

e. **Other etiologies**

Substrate limited

- Ketotic hypoglycaemia
- Poisoning-drugs
- Salicylates
- Alcohol
- Insulin
- Propranolol
- Oral hypoglycaemic agents
- Quinine

Liver disease

- Reyes syndrome
- Hepatitis
- Cirrhosis
- Hepatoma

f. **Aminoacid and organic acid disorders**

- maple syrup urine disease
- propionic academia
- methylmalonic academia
- tyrosinosis

- glutaric aciduria.

g. **Systemic disorders**

- Sepsis
- Carcinoma
- Heart failure
- Malnutrition
- Malabsorption
- Renal failure
- Diarrhoea
- Burns
- Shock
- Falciparum malaria

DIAGNOSIS OF ACUTE HYPOGLYCEMIA IN INFANTS AND CHILDREN:

Acute symptoms present:

1. Blood sample must be taken before and 30 min after glucagon administration.
2. Urine sample must be collected. Look for ketones; if absent and hypoglycaemia confirmed, suspect hyperinsulinemia or fatty acid oxidation defect; if present, suspect ketotic, hormonal deficiency, inborn error of glycogen metabolism, or defective gluconeogenesis.
3. Measure glucose in the original blood sample. If hypoglycaemia is confirmed, proceed with substrate- hormone measurement
4. If glycemic increment after glucagon exceeds 40mg/dl above basal, suspect hyperinsulinemia
5. If insulin level at the time of confirmed hypoglycaemia is >5microU/ml, suspect endogenous hyperinsulinemia; if >100micoU/ml, suspect factitious hyperinsulinemia (exogenous insulin injection). Admit to hospital.
6. If cortisol is<10microg/dl or growth hormone is<5ng/ml, or both, suspect adrenal insufficiency or pituitary disease, or both. Admit to hospital for hormonal testing and neuroimaging.

Acute symptoms not present:

1. Careful history regardingtime and type of food and their relation with symptoms. Assess likelihood of insulin injection, salt craving, growth velocity, intracranial pathology.
2. Careful examination for hepatomegaly (glycogen storage disease; defect in gluconeogenesis); pigmentation (adrenal failure); stature and neurologic status (pituitary disease)

3. Admit to hospital for provocative testing:

24hours fast under careful observation; when symptoms provoked, proceed with above steps 1-4 (when acute symptoms are presen), Pituitary –adrenal function using arginine- insulin stimulation test if indicated

4. Plan for molecular diagnostic test prior to liver biopsy.

TREATMENT:

Acute symptomatic hypoglycaemia:

2ml/kg of 10% dextrose in water, followed by a continuous infusion of glucose at 6-8 mg/kg/min, adjusting the rate to maintain blood glucose levels in the normal range. If hypoglycaemic seizures are present, some recommend a 4ml/kg bolus of D10W.

Treatment of asymptomatic hyperglycemia in at risk infants usually includes enteral feedings. If clinical symptoms develop or the hypoglycaemia persists despite enteral feedings, intravenous glucose is indicated.

If there is persistent infantile hypoglycaemia, gradually increase the rate of intravenous glucose infusion to 10-15mg/kg/min or more, if needed. Central venous catheter may be needed to administer a hypertonic 15-25% glucose solution.

If hyperinsulinism is present, it should be managed medically with Diazoxide and somatostatin analogs.

Surgery- partial or near total pancreatectomy is indicated in refractory hypoglycaemia cases.

HYPERGLYCEMIA

Hyperglycemia is common in critically ill patients. Patients with hyperglycemia could be known diabetic or non-diabetic. Definitely hyperglycemia can increase morbidity and mortality in critically ill patients[83]. Correction of hyperglycemia may improve clinical outcomes. To date, a definite answer with regard to glucose management in general intensive care unit patients, including treatment thresholds and glucose target is undetermined.

Epidemiology of hyperglycemia in critical ill patients:

Hyperglycemia tends to occur in children with undiagnosed or known diabetes or during acute illness (which means stress hyperglycemia) [70]. Hyperglycemia occurs after severe stress (for example injury or infection) and it results from the combination of increased hepatic gluconeogenesis, increased secretion of the catabolic hormones, and resistance to hepatic and peripheral actions of the insulin. Hyperglycemia is one of the common occurrences in the intensive care unit and it is associated with the worse outcomes in both children and adults (Jeremy Clain, Kannan Ramar)[71, 82].

At first, hyperglycemia was assumed to be an adaptive stress response which is favorable to survival (Van Den Berghe 2004)[72]. Hyperglycemia is common among critically ill patients and it is caused due to various mechanisms such as insufficient insulin, nutrition, and medications. Approximately 75 percent of all patients, including diabetes may have blood glucose concentrations more than 110 mg/dl (6.1 mmol/l) during the time of admission and nearly about 12 percent of all patients may have blood glucose concentrations more than 200 mg/dL (11.1 mmol/l) during the time of admission (Berghe et al, 2001)[73].

Pathophysiology of Hyperglycemia In critical ill Patients:

Hansen et al (2007) has mentioned that diabetes mellitus is a generally difficult and strain related hyperglycemia happening in patients devoid of record of diabetes mellitus,which has been exposed to be related with a not so good clinical result[74]. Stress hyperglycemiais typically defined as a recent detected hyperglycemia to be greater than 200 mg/dl (11.1 mmol/l) that resolves subsequent to decision of severe illness. According to Donahey E, (2013) Stress hyperglycemia is triggered by endogenous and exogenous influences[75]. Endogenous influences are counter-regulatory hormones, increased insulin resistance, decreased glucose uptake and increased cytokines. Severe body stress leads to upsurge of cortisol secondary to activation of the hypothalamic– pituitary–adrenal axis. Cortisol will stimulate gluconeogenesis which lead to elevation of blood glucose in addition to that cortisol which reduces glucose utilization. Insulin resistance encouraged more by the effects of other counter-regulatory hormones, such as glucagon, catecholamine, and growth hormone, which enhance lipolysis, proteolysis, and hepatic glucose production. All of these impair peripheral tissue uptake of glucose, increase release of free fatty acids in circulation, and stimulate gluconeogenesis and glycogenolysis.

Treatment of Hyperglycemia in Critically Ill Patient:

As recommended by ADA and AACE in critically ill patient insulin should be started for persistent hyperglycemia, at blood glucose level greater than 180 mg/dL(10 mmol/l). In the ICU setting, insulin infusion should be used to control hyperglycemia and to maintain blood glucose levels between 140 mg/dl to 180 mg/dl (7.8 to 10 mmol/l) and levels less than 110 mg/dL (less than 6.1 mmol/l) are not recommended. Validated protocols with demonstrated safety, efficacy, and low rate of hypoglycemia

are recommended. With IV insulin therapy, frequent glucose monitoring is required (Moghissi, E.S. et al 2009). In critically ill patients to control the hyperglycemia a validated intravenous insulin infusion protocol that has demonstrated efficacy and safety in achieving a target glucose range without increasing the risk of severe hypoglycemia is required as recommended by the American Diabetes Association.

The best insulin infusion protocol should be as :-

a) Blood glucose control reached in a sound timeframe

b) Minimal hypoglycemic risk

c) Have a low operator error rate

d) Require minimal nursing time.

Once the condition of patient stabilizes, infusion of IV insulin can be transitioned to subcutaneous insulin therapy. During the transition to subcutaneous insulin bolus and a basal regimen of insulin has been described to be efficient and protective in surgical and medical patients. The basal insulin is offered as an injection of basal insulin analogs provided every 24 hours or intermediate acting human insulin given every eight to twelve hours. Regular insulin has a gradual action onset and must be injected 30 to 45 minutes before a meal. The safety and effectiveness of premixed preparations of insulin have not been verified in hospitalized patients.

MAINTENANCE AND REPLACEMENT THERAPY:

The ideal maintenance solution and fluid regimen remains a topic of heated debate in Pediatrics. The traditional recommendations for maintenance fluids are increasingly criticized as they do not consistently apply in acute illness, where energy expenditure and electrolyte requirements deviate significantly from the original

estimates. A physiologically based framework for prescribing maintenance fluids is presented, with the objective of maintaining tonicity balance, and infusing the minimum volume of maintenance fluid required to maintain hemodynamics.

Theseare used in children unable to take orally. Children may also require replacement fluids along with maintenance fluids if they have continuousexcessive losses such as NG aspirate, high urine output. Child may also require deficit replacement if dehydration is also present.

GOALS OF MAINTENANCE THERAPY[4]:

1. To prevent dehydration
2. To prevent electrolyte disorders
3. To prevent ketoacidosis
4. To prevent protein degradation

Composition of maintenance fluids are: water, glucose, sodium, potassium. Advantages of this solution are: simplicity, long shelf life, low cost, compatibility with peripheral intravenous administration.

Children lose water, sodium, potassium in their urine and stool; water is also lost from the skin and lungs. These losses are replaced by maintenance fluids. Approximately 20% of the normal caloric needs of the patient are provided by the glucose in the maintenance fluids. It also prevents the development of starvation ketoacidosis, and decreases protein degradation which occur due to decreased or no calories. Adequate calories, proteins, fats, minerals, or vitamins are not provided by the maintenance fluids. Hence, patient will lose about 0.5-1% of weight every day.

MAINTENANCE WATER:

This provides enough water so that the kidney need not significantly dilute or concentrate the urine, also provides a margin of safety, so that normal homeostatic mechanisms can adjust urinary water losses to prevent overhydration and dehydration.

Body weight	**Fluid per day**
0-10 kg	100ml/kg
11-20kg	1,000ml+50ml/kg for each kg>10kg
>20kg	1,500+20ml/kg for each kg>20kg

Table 5: HOLLIDAY-SEGAR FORMULA[81]

INTRAVENOUS SOLUTIONS:

Normal saline and Ringer lactate are isotonic solutions[4]; i.e,same tonicity as plasma. Isotonic fluids without glucose are used for the acute correction of intravascular volume depletion.

Most commonly used intravenous maintenance fluids are half- normal saline and NS. These solutions are available with 5%D or without dextrose. They are also available with 20mEq/l of potassium chloride, 10mEq/l of potassium chloride, or no potassium. Calcium, magnesium, phosphate, acetate, and or bicarbonate, can also be added to intravenous fluids.

Plasma osmolality ranges between 285-295 mOsm/kg[4]. Infusion of an intravenous solution with low osmolality peripherally can lead to movement of water into red blood cells, leading to haemolysis. Thus, intravenous fluids are generally

designed to have an osmolality that is either close to 285 or greater. Thus, 0.2NS should not be administered peripherally, but D5 0.2NS or D51/2 NS+20mEq/l KCL can be administered.

Glucose:

Maintenance fluids mostly contain 5D, which supplies 17 calories/100ml and nearly 20% of the daily caloric needs. This is enough to prevent production of ketone and it also helps in minimizing protein degradation, but weight loss occurs. The weight loss is the main reason for the need of giving TPN after a few days of maintenance fluids if the child is not taking enteral feeds.

Table6:Composition of maintenance fluids

Fluid	**Na+**	**Cl-**	**K+**	**Ca2+**	**lactate**
Normal saline	**154**	**154**	**-**	**-**	**-**
Half normal saline	**77**	**77**	**-**	**-**	**-**
0.2 normal saline	**34**	**34**	**-**	**-**	**-**
Ringer lactate	**130**	**109**	**4**	**3**	**28**

Choice of maintenance fluids:

D5 1/2NS +20Meq/L KCL is suggestedin the child who is nil by mouth and does not have volume depletion or risk factors for nonosmotic ADH production.

Children with volume depletion, baseline hyponatremia, or at risk for non osmotic ADH production should receive D5NS+ 20mEq/l KCL. Children who have underwent surgical procedures need to receive isotonic fluids during surgery and in the recovery room for 6-8 hours postoperatively; the rate is approximately two-thirds of the calculated maintenance rates, and dextrose must be added if clinically needed. Subsequent maintenance fluids should be D5 NS or RL, with addition of 10-20 mEq/l of KCL based on the serum potassium and the clinical setting.

Electrolytes must be measured once in a day in all children receiving more than 50% of maintenance fluids intravenously. It is critical to monitor weight, urine output and electrolytes to identify overhydration, hyponatremia, other electrolyte disturbances, and to then adjust the rate or composition of the intravenous solution accordingly.

Study by JingJing W Erdi X Yangfeng X showed significant risk of developing hyponatremia by using hypotonic IV fluids[76].

Sarah McNab, et al showed that isotonic intravenous fluids use had a low risk of developing hyponatremia as compared to hypotonic intravenous fluid[77].

A study by Montanana PA et al showed that after 24 hours of infusion, patients receiving hypotonic fluids had lower natremia levels and higher incidence of hyponatremia[78].

Variations in maintenance water and electrolytes:

The calculation of maintenance water is based on standard assumptions regarding water losses. There are patient,however, in whom these assumptions are incorrect. To identify such situations, it is helpful to understand the source and magnitude of normal water losses.

SOURCES OF WATER LOSS: urine(60%), insensible losses(35%), stool(5%).Most important contribution to the normal water losses is by urine. Insensible losses are approximately one third of total maintenance water.

Depending on the clinical condition of the child maintenance water can be increased or decreased.

A study by Choong K, Bohn D concluded that maintenance fluid preparations should be individualized. No single intravenous solution is ideal for every child during all phases of illness, but there is evidence to suggest that the safest empirical choice is an isotonic solution. Hypotonic solutions should only be considered if the goal is to achieve a positive free water balance.

A study by Shamim A mentioned that energy expenditure in critically ill children has been found to be as low as 50- 60 Kcal/Kg/day, by indirect calorimetric measurements. Fluid requirement is much less in critically ill children for a variety of reasons such as physical immobility, the use of muscle relaxants and sedatives, mechanical ventilation, and additional factors such as nonessential or facultative metabolism. Moreover, fluid requirement is further decreased because of inappropriate increase in arginine vasopressin which impairs the kidney's ability to excrete free water.

METHODOLOGY

Source of data:

Prospective study comprising of critically ill children admitted in Pediatric ICU of Shri.B.M.Patil Medical College Hospital and Research Centre, Vijayapur from November 2015 to April 2017.

Methodology:

At the time of admission the patient's clinical picture is recorded in proforma. Venous blood sampling is obtained from each patient enrolled in the study, blood containing bulbs are labelled and kept aside for serum separation and sent for estimation of Electrolytes, Glucose without delay. Reports are then collected and interpreted. Patient was followed up till discharge or death.

Other investigations were done as per the need of the patient.

Outcome in terms of electrolyte disturbance, discharge status or death was recorded.

Inclusion criteria:

Based on consensus guidelines for PICUs in India, Indian society of critical care medicine (Pediatric section) and Indian academy of Paediatrics (intensive care chapter)[80].

All PICU admitted children of age group 1 month to 15 years.

Exclusion criteria:

1. Patients known or diagnosed to have chronic renal or hepatic disease.
2. Patients known to have metabolic disorders like Diabetes mellitus, Adrenal diseases etc.
3. Any condition with known abnormality of Glucose or electrolytes.

Serum electrolytes were estimated using VITROS 250 Analyzer system.

The data collected were analysed for the frequency of various electrolyte imbalances, system wise distribution of illnesses associated with electrolyte imbalances, correlation of outcome to the severity of dyselectrolytemia, and mortality in relation to electrolyte imbalances and correlation of these electrolyte imbalances with the maintenance fluid used.

SAMPLE SIZE:153 calculated as per following formula.

With 95% confidence level, anticipated prevalence of electrolyte disturbance as 90% and desired precision as +/- 5%, the minimum sample size is 139(~153).

Actual sample size =139~153

Formula used=Z^2 P(1-P)/D^2

Z-Statistic for a level of confidence

P-expected prevalence

D-Desired precision.

=$(1.96)^2$x90(10)/$(5)^2$

=138.2

~139

Statistical analysis:

All characteristics were summarized descriptively. For continuous variables, the summary statistics of mean, standard deviation (SD) were used. For categorical data, the number and percentage were used in the data summaries. Chi-square (χ^2)/ Freeman-Halton Fisher exact test was employed to determine the significance of differences between groups for categorical data. If the p-value was < 0.05, then the results were considered to be statistically significant otherwise it was considered as not statistically significant. Data were analyzed using SPSS software v.23.0.and Microsoft office.

IMAGES

PEDIATRIC INTENSIVE CARE UNIT

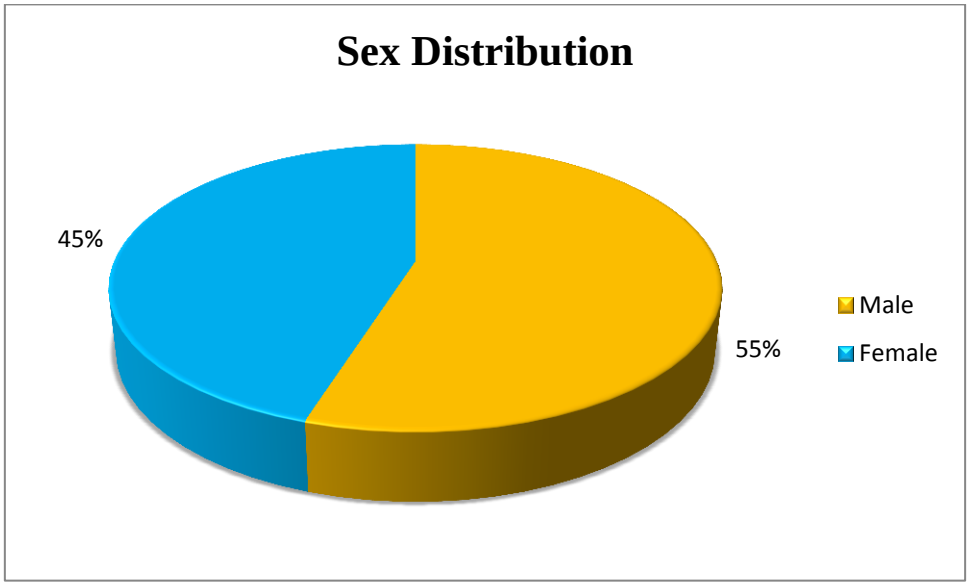
VITROS 250 ANALYZER SYSTEM

RESULTS

Table 7: Distribution of cases based on their gender

SEX	N	%
Male	84	54.9
Female	69	45.1
Total	153	100

Graph 1: Pie diagram showing gender wise distribution of 153 cases.



Shows maximum of 55% were male and 45% were female.

Table 8: Gender ratio of cases.

M/F ratio	1.2

Shows male to female ratio was 1.2:1.

Table 9: Distribution of cases by Age

Age (Yrs)	N	%
<1	36	23.5
1-2	36	23.5
3-5	25	16.3
>5	56	36.6
Total	153	100.0

Graph 2: Pie diagram showing distribution of cases by Age

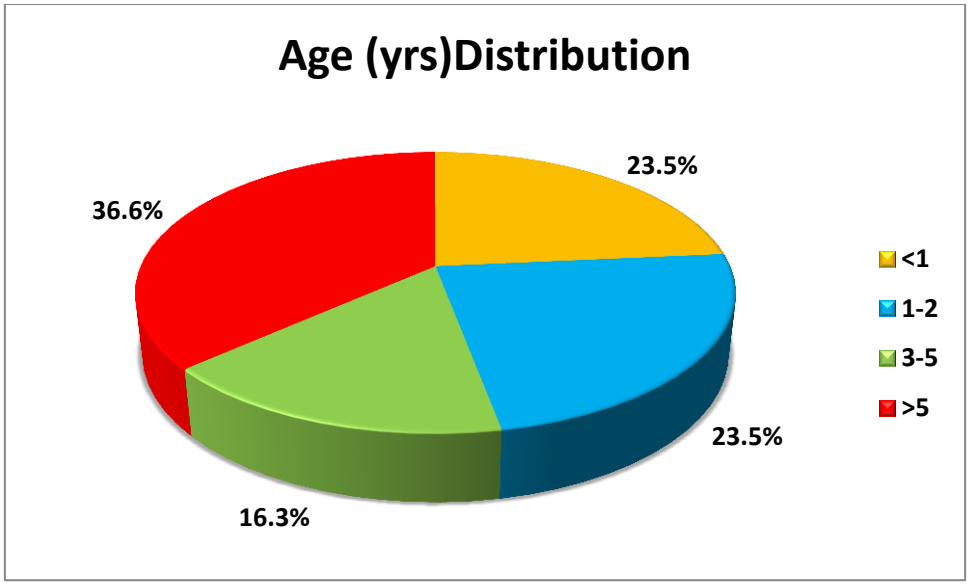


Table 10: Mean Age

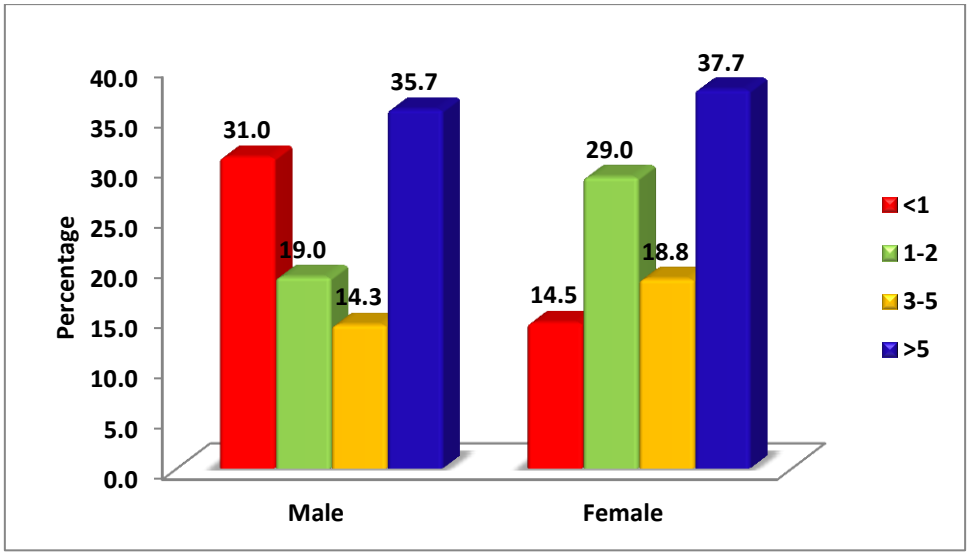
Age (Yrs)	Minimum	Maximum	Mean	SD
	0.1	14	4.8	4.4

Shows maximum belonged to age group of >5 years with a mean age of 4.8years.

Table 11: Distribution of cases based on their age and sex

Age (Yrs)	Male		Female		Chisqr p value
	N	%	N	%	
<1	26	31.0	10	14.5	0.091
1-2	16	19.0	20	29.0	
3-5	12	14.3	13	18.8	
>5	30	35.7	26	37.7	
Total	84	100.0	69	100.0	

Graph 3: Distribution of cases based on their age and sex

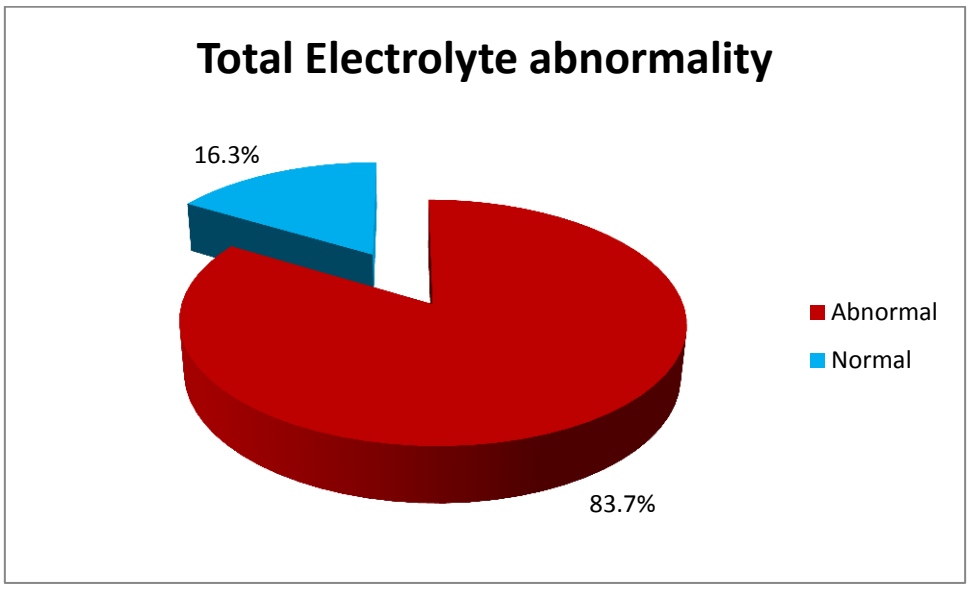


Shows there was difference in distribution of male and female cases among different age groups but it was not statistically significant.

Table 12: percentage of electrolyte abnormality in PICU

Total Electrolyte abnormality	**N**	**%**
Abnormal	128	83.7
Normal	25	16.3
Total	153	100.0

Graph 4: Pie diagram showing percentage of electrolyte abnormality in PICU

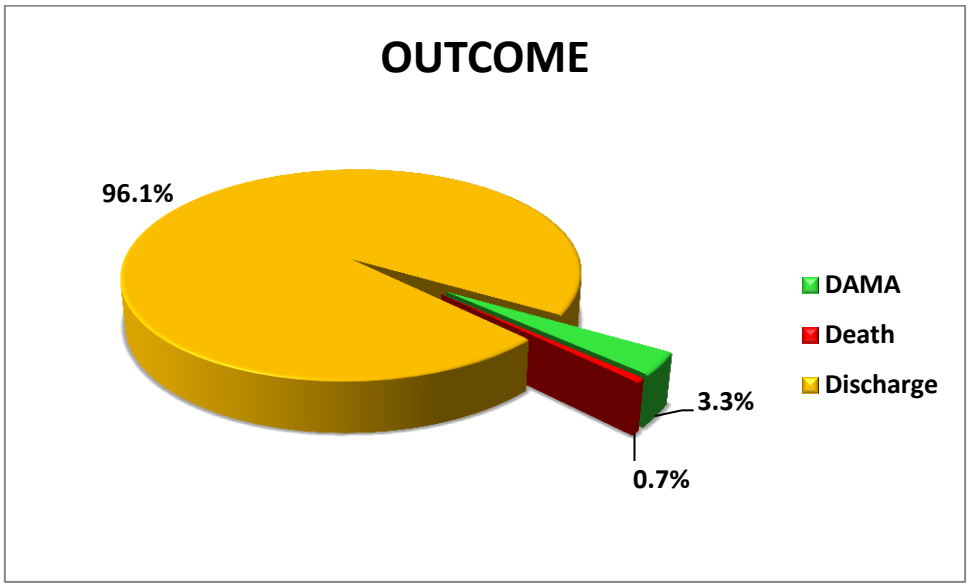


Shows 128 cases (83.7%) had electrolyte abnormality.

Table 13: Distribution of cases by Outcome

OUTCOME	N	%
DAMA	5	3.3
Death	1	0.7
Discharge	147	96.1
Total	153	100.0

Graph 5: Distribution of cases by Outcome



*DAMA- Discharge against medical advice

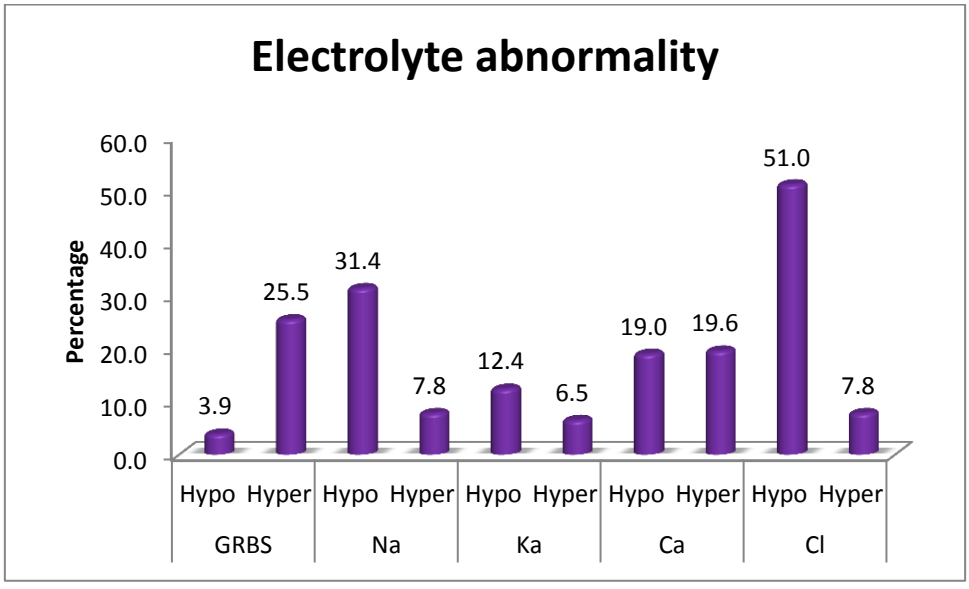
Shows 147 (96.1%) cases were discharged, 5 (3.3%) cases were discharged against medical advice, and 1 (0.7%) case died

1 case which died had mixed electrolyte abnormality.

Table 14: Distribution of cases based on electrolyte imbalance**.**

Electrolyte abnormality		**N**	**%**
Blood glucose	Hypoglycemia	6	3.9
	Hyperglycemia	39	25.5
Na^+	Hyponatremia	48	31.4
	Hypernatremia	12	7.8
K^+	Hypokalemia	19	12.4
	Hyperkalemia	10	6.5
Ca^{2+}	Hypocalcemia	29	19.0
	Hypercalcemia	30	19.6
Cl^-	Hypochloremia	78	51.0
	Hyperchloremia	12	7.8

Graph 6: Distribution of cases based on electrolyte imbalance

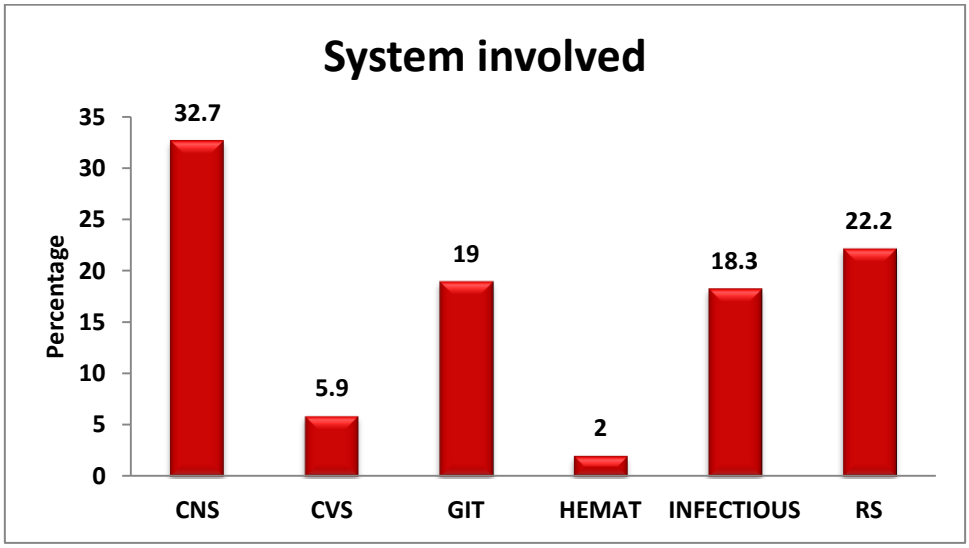


Shows 78 (51%) cases had Hypochloremia, followed by 48 (31.4%) cases with Hyponatremia, 39 (25.5%) cases with Hyperglycemia, 30 (19.6%) cases with Hypercalcemia, 29 (19%) cases with Hypocalcemia, 19(12.4%) cases with Hypokalemia, 12 (7.8%) cases each with Hypernatremia and Hyperchloremia, 10 (6.5%) cases with Hyperkalemia, 6 (3.9%) cases with Hypoglycemia.

Table 15: Distribution of cases by System involved

System involved	N	%
CNS	50	32.7
CVS	9	5.9
GIT	29	19
HEMAT	3	2
INFECTIOUS DISEASE	28	18.3
RS	34	22.2
Total	153	100

Graph 7: Distribution of cases by System involved

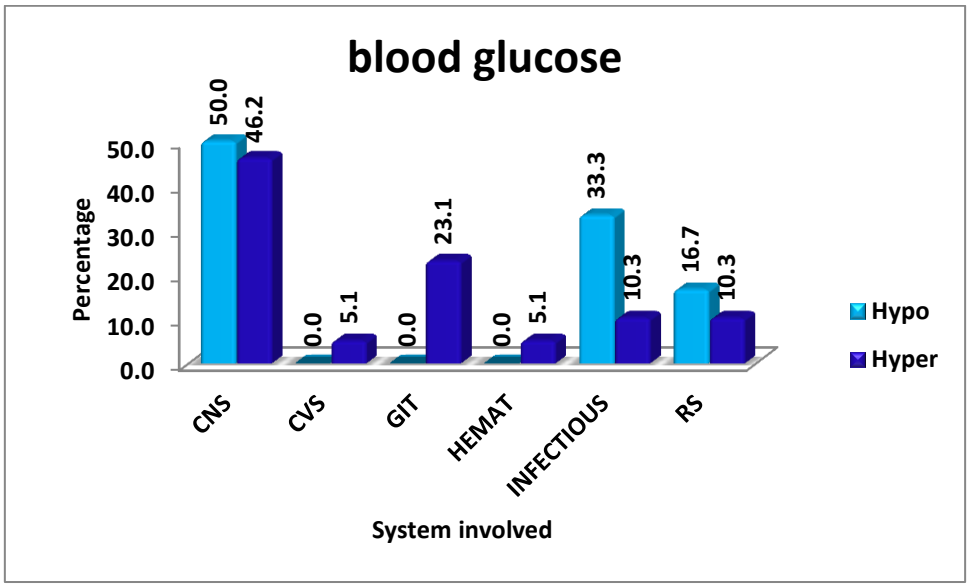


Shows 50 cases (32.7%) had CNS disease, 34 cases (22.2%) had respiratory disease, 29 (19%) had GI problems, 28 (18.3%) suffered from infectious diseases, 9 (5.9%) had CVS involvement and 3 (2%) had hematogical system involvement.

Table 16: Distribution of cases by System involved with blood glucose abnormality

System involved	Blood glucose			
	Hypoglycemia		Hyperglycemia	
	N	%	N	%
CNS	3	50.0	18	46.2
CVS	0	0.0	2	5.1
GIT	0	0.0	9	23.1
HEMATOLOGY	0	0.0	2	5.1
INFECTIOUS	2	33.3	4	10.3
RS	1	16.7	4	10.3
Total	6	100.0	39	100.0

Graph 8: Distribution of cases by System involved with blood glucose abnormality

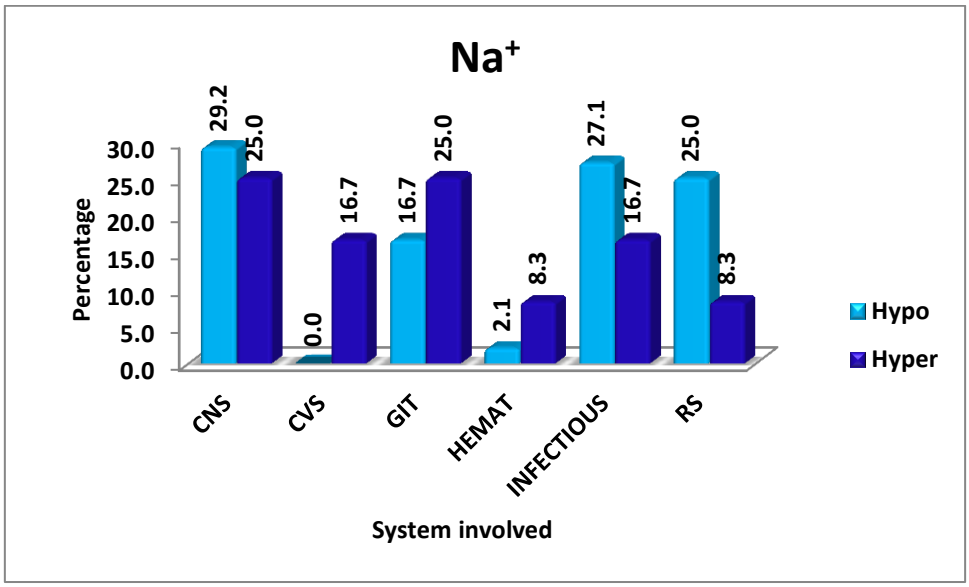


Shows 50% cases with Hypoglycemia had CNS disease, followed by 33.3% cases due to Infectious diseases and 46.2% cases with Hyperglycemia also had CNS disease, followed by 23.1% with GI diseases.

Table 17: Distribution of cases by System involved with Na^+ abnormality

System involved	Na^+			
	Hyponatremia		Hypernatremia	
	N	%	N	%
CNS	14	29.2	3	25.0
CVS	0	0.0	2	16.7
GIT	8	16.7	3	25.0
HEMATOLOGY	1	2.1	1	8.3
INFECTIOUS	13	27.1	2	16.7
RS	12	25.0	1	8.3
Total	48	100.0	12	100.0

Graph 9: Distribution of cases by System involved with Na^+ abnormality



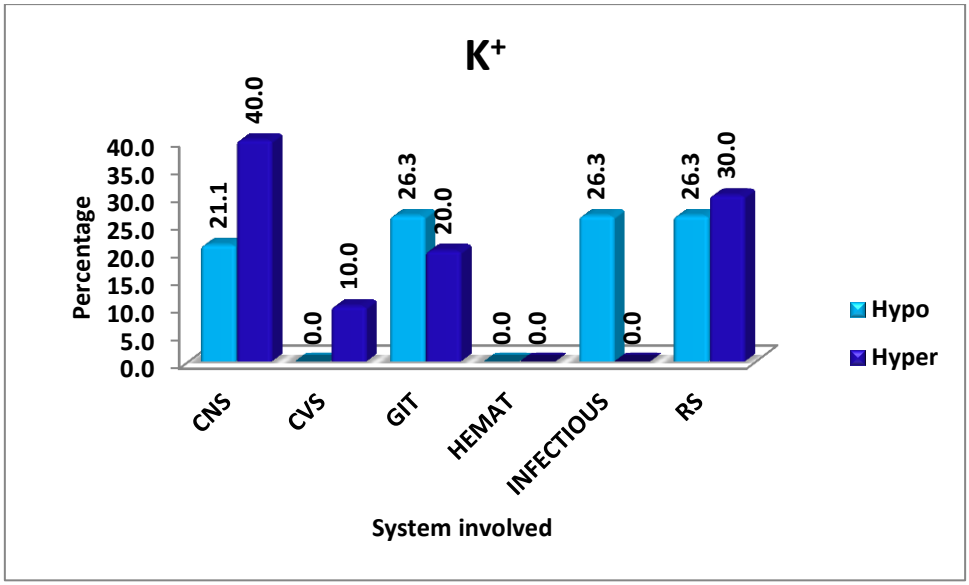
Shows 29.2% (14) cases with Hyponatremia had CNS disease, followed by 27.1% (13) cases due to Infectious diseases, followed by 25% (12) cases with respiratory disease.

25% (3) cases each with Hypernatremia had CNS disease and GI disease.

Table 18: Distribution of cases by System involved with K^+ abnormality

System involved	K^+			
	Hypokalemia		Hyperkalemia	
	N	%	N	%
CNS	4	21.1	4	40.0
CVS	0	0.0	1	10.0
GIT	5	26.3	2	20.0
HEMATOLOGY	0	0.0	0	0.0
INFECTIOUS	5	26.3	0	0.0
RS	5	26.3	3	30.0
Total	19	100.0	10	100.0

Graph 10: Distribution of cases by System involved with K^+ abnormality

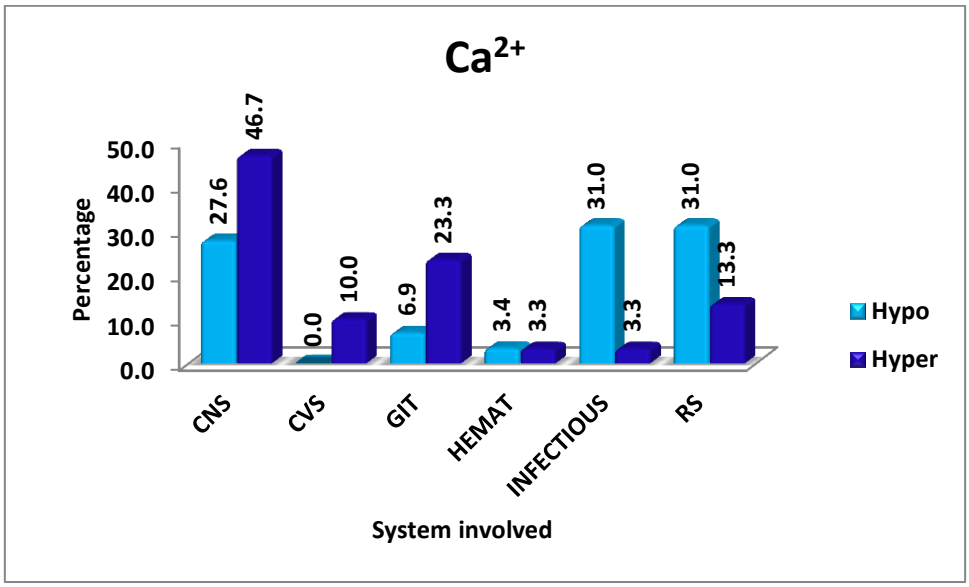


Shows 26.3% (5) cases each with Hypokalemia had GI disease, Infectious disease, respiratory disease.40% (4) cases with Hyperkalemia had CNS disease, followed by 30% (3) cases due to respiratory disease.

Table 19: Distribution of cases by System involved with Ca^{2+} abnormality

System involved	Ca^{2+}			
	Hypocalcemia		Hypercalcemia	
	N	%	N	%
CNS	8	27.6	14	46.7
CVS	0	0.0	3	10.0
GIT	2	6.9	7	23.3
HEMATOLOGY	1	3.4	1	3.3
INFECTIOUS	9	31.0	1	3.3
RS	9	31.0	4	13.3
Total	29	100.0	30	100.0

Graph 11: Distribution of cases by System involved with Ca^{2+} abnormality

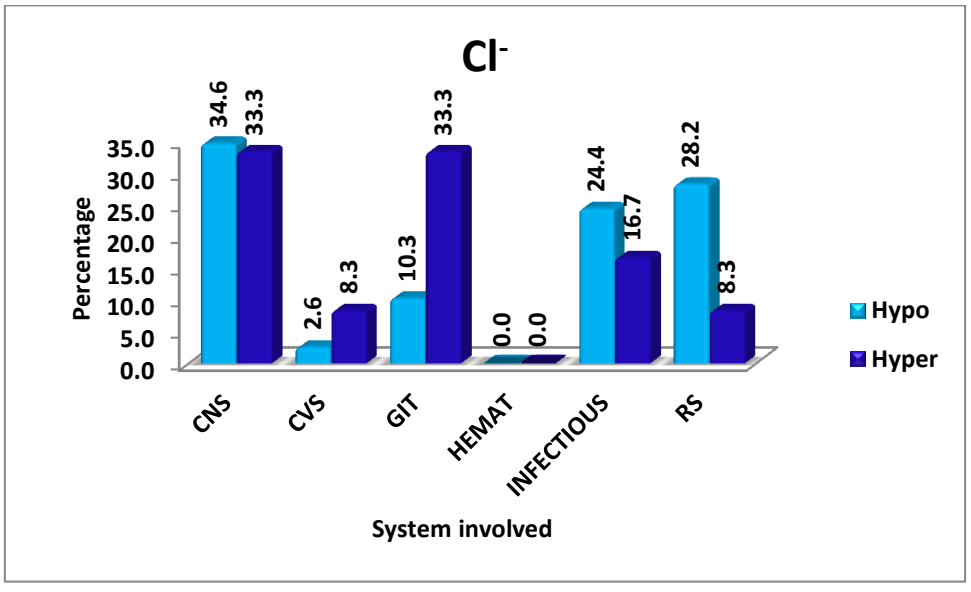


Shows 31% (9) cases each with Hypocalcemia had Infectious disease and respiratory disease46.7% (14) cases with Hypercalcemia had CNS disease, followed by 23.3% (7) cases with GIT disease.

Table 20: Distribution of cases by System involved with Cl^- abnormality

System involved	Cl^-			
	Hypochloremia		Hyperchloremia	
	N	%	N	%
CNS	27	34.6	4	33.3
CVS	2	2.6	1	8.3
GIT	8	10.3	4	33.3
HEMAT	0	0.0	0	0.0
INFECTIOUS	19	24.4	2	16.7
RS	22	28.2	1	8.3
Total	78	100.0	12	100.0

Graph 12: Distribution of cases by System involved with Cl^- abnormality



Shows 34.6% (27) cases with Hypochloremia had CNS disease, followed by 28.2% (22) cases due to respiratory disease, 33.3% (4) cases each with Hyperchloremia had CNS and GIT disease.

Table 21: Correction of abnormality with DNS fluid

Electrolyte		Total abnormal at beginning	Corrected	Not corrected	% corrected
Blood glucose	**Hypoglycemia**	1	1	0	100.0
	Hyperglycemia	4	3	1	75.0
Na^+	**Hyponatremia**	6	2	4	33.3
	Hypernatremia	1	1	0	100.0
K^+	**Hypokalemia**	5	1	4	20.0
	Hyperkalemia	0	0	0	0.0
Ca^{2+}	**Hypocalcemia**	3	1	2	33.3
	Hypercalcemia	1	1	0	100.0
Cl^-	**Hypochloremia**	8	2	6	25.0
	Hyperchloremia	1	0	1	0.0

Shows Hyponatremia which was seen at admission was corrected (100%) after giving DNS as maintenance fluid. Hypernatremia was also corrected 100% after giving DNS for 24 hours. Same was observed with Hypercalcemia.

Table 22: Correction of abnormality with Isolyte Pfluid.

Electrolyte		Total abnormal at beginning	Corrected	Not corrected	% corrected
Blood glucose	**Hypoglycemia**	3	3	0	100.0
	Hyperglycemia	10	6	4	60.0
Na^+	**Hyponatremia**	12	7	5	58.3
	Hypernatremia	3	2	1	66.7
K^+	**Hypokalemia**	2	1	1	50.0
	Hyperkalemia	6	4	2	0.0
Ca^{2+}	**Hypocalcemia**	7	3	4	42.9
	Hypercalcemia	10	3	7	30.0
Cl^-	**Hypochloremia**	17	5	12	29.4
	Hyperchloremia	4	2	2	50.0

Shows 24 hours after giving Isolyte P as maintenance fluids, there was 100% correction in hypoglycemia, followed by Hypernatremia (66.7%).

Table 23: Correction of abnormality with 0.45% DNS (FLUSODEX) fluid

Electrolyte		**Total abnormal at beginning**	**Corrected**	**Not corrected**	**% corrected**
Blood glucose	**Hypoglycemia**	2	1	1	50.0
	Hyperglycemia	21	12	9	57.1
Na^+	**Hyponatremia**	25	14	11	56.0
	Hypernatremia	6	5	1	83.3
K^+	**Hypokalemia**	10	4	6	40.0
	Hyperkalemia	2	2	0	0.0
Ca^{2+}	**Hypocalcemia**	14	4	10	28.6
	Hypercalcemia	18	12	6	66.7
Cl^-	**Hypochloremia**	44	13	31	29.5
	Hyperchloremia	6	4	2	66.7

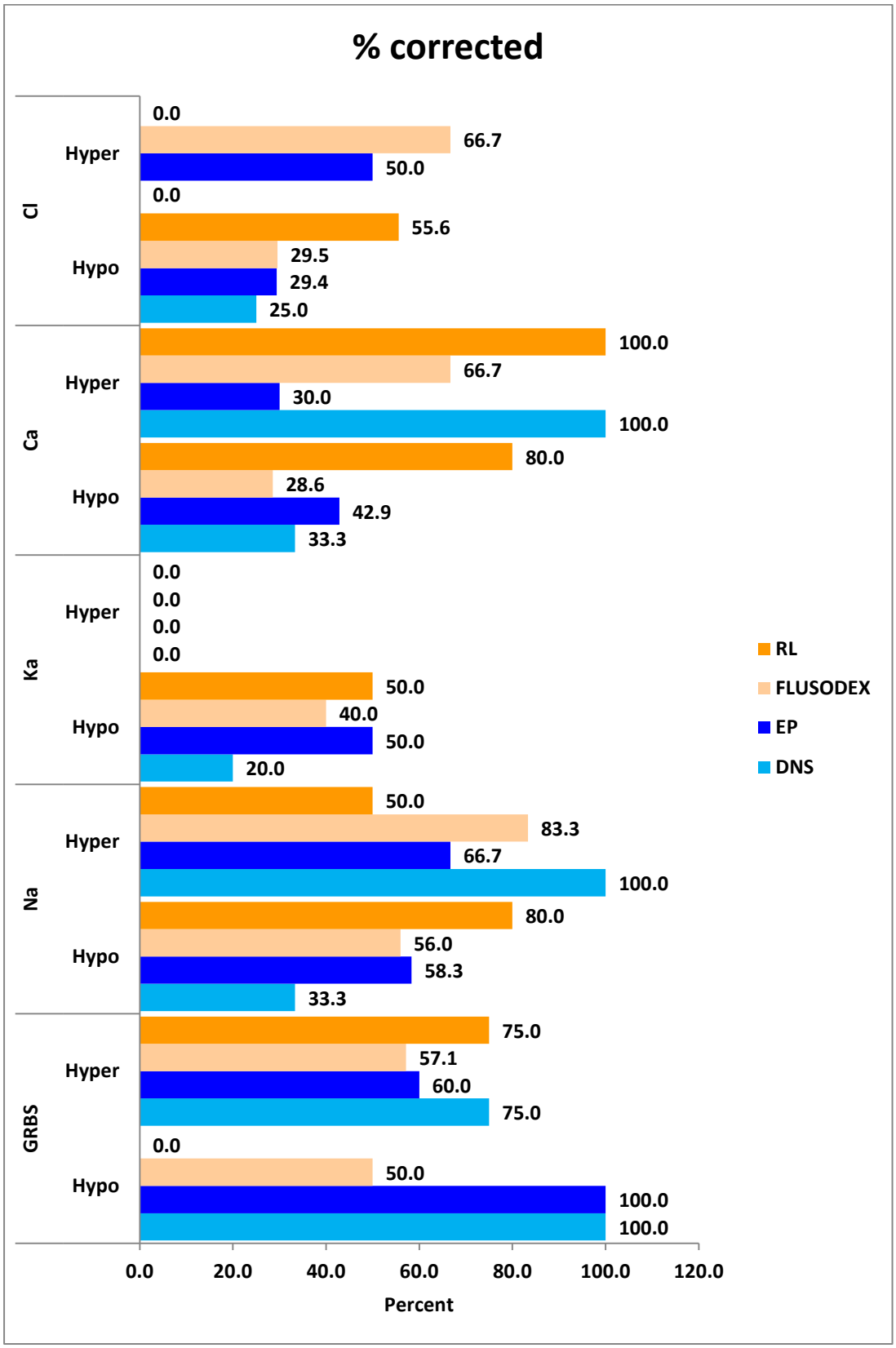
Shows there was 83.3% correction in Hypernatremia after giving flusodex (0.45% DNS), 66.7% correction in Hypercalcemia and Hyperchloremia, 57.1% correction in Hyperglycemia, 56% correction in Hyponatremia.

Table 24: Correction of abnormality with RL fluid

Electrolyte		Total abnormal at beginning	Corrected	Not corrected	% corrected
Blood glucose	**Hypoglycemia**	0	0	0	0.0
	Hyperglycemia	4	3	1	75.0
Na^+	**Hyponatremia**	5	4	1	80.0
	Hypernatremia	2	1	1	50.0
K^+	**Hypokalemia**	2	1	1	50.0
	Hyperkalemia	2	1	1	0.0
Ca^{2+}	**Hypocalcemia**	5	4	1	80.0
	Hypercalcemia	1	1	0	100.0
Cl^-	**Hypochloremia**	9	5	4	55.6
	Hyperchloremia	1	0	1	0.0

Shows there was 100% correction in Hypercalcemia after giving RL as maintenance fluid. 80% correction in both Hyponatremia and Hypocalcemia.75% correction in Hyperglycemia.

Graph 13: %Correction of abnormality with IV fluids



Shows100% correction in Hypoglycemia after giving DNS and Isolyte P as maintenance fluids.75% correction in Hyperglycemia after giving RL and DNS as maintenance fluids.

80% correction in Hyponatremia after giving RL as maintenance fluid. 100% correction in Hypernatremia after giving DNS and 83.3% after giving 0.45%DNS as maintenance fluids.

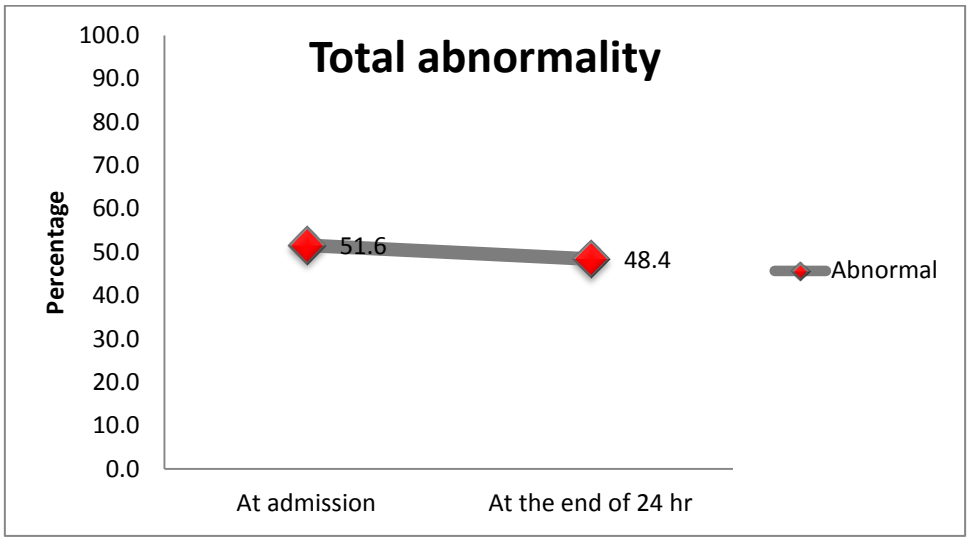
50% correction in Hypokalemia after giving RL and Isolyte P as maintenance fluids.

80% correction in Hypocalcemia after giving RL as maintenance fluid and 100% correction in Hypercalcemia after giving DNS and RL as maintenance fluids.

There was 55.6% correction in Hypochloremia after giving RL and 66.7% correction in Hyperchloremia after giving 0.45%DNS as maintenance fluid.

Overall use of DNS as maintenance fluid led to correction of the following electrolyte imbalances: Hypoglycemia, Hypernatremia, Hypercalcemia and use of RL as maintenance fluid led to correction of Hypercalcemia, Hyponatremia, Hyperglycemia.

Graph 14: Change in total electrolyte abnormality cases after 24 hours



Shows overall electrolyte abnormality which was 51.6% at admission reduced to 48.4% at the end of 24 hours.

DISCUSSION

Frequency of electrolyte imbalances:

Electrolyte abnormalities were observed in 83.7% of children getting admitted to PICU. Thus it's a fairly common occurrence in an intensive care unit set up.

A study done by Subbarao SD[2], Biju Thomas showed that of the 305 patients admitted in PICU, 99 (32.45%) patients had electrolyte abnormality.

A similar study showed that of the total 254 patients admitted in Pediatric ICU, 109 (42.91%) patients had electrolyte abnormalities.

CNS (32.7%) was the most common system in my study followed by 22.2% with Respiratory illness and 19% were due to Gastrointestinal disease,18.3 % due to infectious disease, 5.9% due to cardiovascular problems, 2% with haematological disorders.

A similar study showed, of the 254 patients admitted in PICU, 86 (33.8%) patients had CNS disease followed by 20.4% with respiratory disease, 7.8% with infectious disease. Results are consistent with my study. Another study by Gauri s, et al[84] showed that of the 230 children admitted to PICU, 33% had respiratory diseases, 18.6% had CNS disease, 11.3% had infectious disease, 7.4% had gastrointestinal disease, 6.5% had cardiovascular disease, 1.3% had haematological disease. This correlates with my study.

Among, the various electrolyte abnormalities detected in patients getting admitted to PICU, **Hypochloremia** was the commonest (accounting for 51% of all PICU admissions).

Very little is known about the clinical effects of chloride in critically ill patients. A study conducted by Makiko et al[85] showed that out of 448 cases, 43

patients (8.8%) had hypochloremia and the serum levels of sodium were also lower in about 50% of the hypochloremic group.However, multiple regression analysis showed that chloride was not an independent factor of poorer outcome.Hypochloremic patients were more prevalent in medical admissions, with hypochloremia correlating significantly with higher APACHE II scores. This study indicates that hypochloremia has clinical importance as an indicator of prognosis in critically ill patients.

To the best of our knowledge we dint find any other study on the prevalence of hyperchloremia or hypochloremia in the critical care setting.

Hyponatremia was the second most common electrolyte abnormality found in my study (31.4%) of all PICU admissions. This correlates with observation made in a prospective study of 727 sick children admitted in PICU, done by S.Singhi et al., [39] at PGIMER, Chandigarh.

In another study, 34% of the hospitalized patients were classified as hyponatremic.

In a prospective study done by Devita et al[86] found that the incidence of hyponatremia was 29.6% in patients admitted to the hospital, this corresponds with my study.

In another study done by Nair V et al[87] among 730 patients incidence of hyponatremia was 27.9% and this correlates with my study.

In my study among the patients with Hyponatremia, CNS disease (29.8%) was the commonest cause of hyponatremia, followed by infectious diseases (27.1%) and respiratory infections (25%).

This correlates with a study done by S.Singhi[39] at al where CNS 33% was commonest cause of hyponatremia.

In another study done by Subba Rao et al[2]have found 41.4% cases of hyponatremia suffering from CNS diseases which was the leading cause of Hyponatremia followed by infectious diseases. This correlates with my study.

In another study done by S. Sitaraman, Manish Saxena[88] incidence of hyponatremia was 37% and meningitis/encephalitis (20.5%) was the leading cause.

In another study by Indira Jayakumar et al[89], hyponatremia was most common among children with CNS infectious.

In my study hyponatremia was 80% corrected at the end of 24 hours after using RL as the maintenance fluid. In a study by Corsino et al[90], it was found that blood sodium levels of patients receiving hypotonic fluids decreased by 3.22 mmol/L, hence, hypotonic fluids increase the incidence of hyponatremia whereas isotonic fluids do not cause hyponatremia and should be considered as standard maintenance fluid. Results are in consistent with my study.

In another study by Alexander B et al[91], it was found that administration of isotonic fluid did not increase the risk for hyponatremia.This correlates with my study.

Study by Jeremy et al[92] found that use of isotonic maintenance fluids is safe and may result in fewer cases of hyponatremia.

Hyperglycemia was the third most common electrolyte abnormality noted in my study which accounted for 25.5% of all PICU admissions. This was seen mainly in CNS disorders (46.2%), followed by GI diseases (23.1%), followed by infectious disease (10.3%) and respiratory diseases (10.3%).

A retrospective study by Srinivasan, et al[83] reported that hyperglycemia at 24 hours was present in 54% cases. This correlates with my study.

Another study by Preissig, et al[93]also showed that 51% of children admitted in PICU were Hyperglycemic. This correlates with my study.

Study by Banani Poddar[94] done at Sanjay Gandhi institute of Medical sciences, Lucknow also concluded that Hyperglycemia is common in critically ill children and is associated with a poor outcome.

In another study done by Vinayak KP, Swati BC[95] out of the 101 patients included in the study incidence of Hyperglycemia was 69.3% in children admitted to PICU. 81.8% were Infective cases, 71.4% were neurological cases, 64% were respiratory diseases, 62.5% were diarrhoeal cases.

In another study by Rakesh L[96], et al hyperglycemia was seen in 53.9% children admitted in PICU.

Study by Jain H, Arya S et al[97], showed that the prevalence of hyperglycemia was 58% and was associated with higher mortality rate and longer duration of PICU stay.

David B, Mervyn S[98] concluded that hyperglycemia causes harm through a variety of mechanisms, and this damage is accentuated in the critically ill due to activation of multiple inflammatory processes.

Since the sample size of my study was small the prevalence was not as high as in other studies. This strikingly higher incidence in our critically ill study population underscores the need to recognize that hyperglycemia is common in such acutely ill children.

In my study it was found that after giving RL and DNS for 24 hours as maintenance fluid there was 75% correction in Hyperglycemia.

In a study byVinayak KP, Swati BC[96] regarding hyperglycemia in critically ill children all patients received Dextrose containing I V fluids. This corresponds with my study.

Hypercalcemia was detected in 19.6% children admitted in our PICU and was fourth in order of frequency in my study.

Study by Ruiz MP et al[99] showed that out of the 360 children admitted in PICU the incidence of Hypercalcemia was 5.8%.

Hypercalcemia was mainly associated with CNS diseases (46.7%), followed by 23.3% ingastrointestinal diseases in my study.

In other studies it was shown that severe hypercalcemia is frequently associated with neurological, gastrointestinal and renal diseases.

In my study RL and DNS were used mainly in cases with Hypercalcemia and there was 100% correction in electrolyte abnormality with these two fluids.

A study by David G[100]concluded that hydration with normal saline is must in every patient with acute, severe hypercalcemia to correct ECF deficit. This correlates with my study.

Similar study by Shane E, Berenson JR[101] concluded that in severe hypercalcemia volume expansion must be done with isotonic saline.

Hypocalcemia was seen in 19% children admitted to PICU in my study. 31% each association was seen with Infectious disease and respiratory diseases, followed by 27.6% in CNS diseases.

In a study by Mohammed BW et al[102] it was shown that out of the 39 critically ill children, serum total calcium in all groups was significantly lower in control groups.

In a prospective study by Singhi S[39], Singh J it was seen that out of 100 children admitted in PICU, the incidence of hypocalcemia was 22.4%. This correlates with my study.

Another study by Muller et al[103], showed that critical illness per se was associated with decreased serum calcium with the severity of the underlying disease.

In my study there was 80% correction in electrolyte abnormality after using RL as maintenance fluid flowed by Isolyte P (42.9%), DNS (33.3%), 0.45%DNS (28.6%).

In my study **Hypokalemia** was seen in 7.8% children admitted in PICU. Gastrointestinal system, infectious diseases, respiratory infectious accounted for 26.3% each of all cases with hypokalemia, followed by 21.1% in CNS disorders.

In a study done by Subba Rao et al[2] also shown that hypokalemia was the least common electrolyte abnormality. A three times higher frequency was observed in two other similar studies done by S. Singhi et al[39] and Singhi.S and Murudkar .A[55] (13.9-14%) as their study included acute gastroenteritis of (20%) which was most common cause of hypokalemia in their study.

In my study there was 50% correction in hypokalemia after using RL and Isolyte P (0.2% NS) as maintenance fluids, followed by 40% with 0.45% DNS, 20% with DNS.

Study by Singhi. S and Murudkar.A[55],concluded that use of higher potassium content of maintenance IV fluids corrected mild to moderate hypokalemia. This correlates with my study.

Hypernatremia was detected in 7.8% of the children getting admitted to PICU in my study. Similar study by G. Lindner et al, incidence of hypernatremia was 9%.

Another study by Thomas B, Subba rao[2] showed that the incidence of hypernatremia was 4.9% in children admitted to PICU.

Hypernatremia was seen most commonly in CNS and gastrointestinal diseases (25% each), followed by 16.7% each in cardiovascular disease and infectious disease, 8.3% each in hematologic and respiratory illness. This correlates with study by Subba Rao et al[2] where CNS disease had 26.7% association with hypokalemia.

In a Study by ML Moritz, Carlos Juan[104] gastroenteritis contributed to 20% of cases with hypernatremia in children. This corresponds with my study. But in majority of cases in their study the cause for hypernatremia was inadequate fluid intake (76%).

In my study it was observed that use of DNS as maintenance fluid led to 100% correction in electrolyte abnormality, followed by 83.3% with 0.45% DNS, 66.7% with Isolyte P, 50% with RL.

In a study by Mohammed et al[105], in children with diarrhea related hypernatremic dehydration, normal saline was safe rehydration fluid.

A study by Kim SW[106] concluded that isotonic saline is unsuitable for correction hypernatremia since the extracellular fluid volume may become overloaded. Hence, hypotonic fluid is recommended.

Another study by Lindner G[107] concluded that hypernatremia must be treated by the administration of free water.

Hyperchloremia was seen in 7.8% of children admitted to PICU. It was mainly associated with CNS and gastrointestinal disorders which accounted for 33.3% each,

followed by infectious diseases (16.7%), 8.3% each with cardiovascular and respiratory illness.

It was seen that use of maintenance fluids like 0.45%DNS and Isolyte P led to the correction in hyperchloremia by 66.7% and 50% respectively.

A study by Broccard SP, Bhargava M[108] concluded that lactated ringer lactate solution prevents hyperchloremia in critically ill neurologic patients. This differs from my study.

Hyperkalemia was seen in 6.5 % of patients admitted to PICU in my study. CNS disease accounted for 40% of cases of hyperkalemia in my study followed by 30% by respiratory illness, 20% by gastrointestinal diseases, 10% by cardiovascular diseases. Similar study by S. Singhi et al[39], hyperkalemia accounted for 5.4% cases admitted in PICU. This correlates with my study.

A prospective study by Subba Rao et al[2] showed that the incidence of hyperkalemia was 14.4%.

Hypoglycemia was seen in 3.9% children admitted in PICU.

Study done by Wintergerst et al[109] in 13 months duration showed that the prevalence of hypoglycemia was 18.6%

Another study by Vriesendorp et al[110], out of the 2272 patients included in the study, 156 (6.9%) patients experienced at least on episode of hypoglycemia.

46.2% cases were associated with CNS disorders followed by 33.3% due to infectious diseases, 16.7% cases due to respiratory illness.

In a study by Krinsley et al[111], multivariable logistic regression analysis identified diabetes, septic shock, renal insufficiency, mechanical ventilation, severity of illness as independent risk factors for the development of hypoglycemia.

Another study by Naranje K, Poddar, Arpita, Baronia[112] showed that 30.8% children had hypoglycemia. Insulin use was associated with hypoglycemia.

In my study it was found that hypoglycemia was 100% corrected at the end of 24 hours after using DNS and Isolyte P as intravenous maintenance fluids, followed by 0.45%DNS (50%) correction in electrolyte abnormality.

In many other studies it was shown that after the bolus is administered, and IV infusion that matches normal hepatic glucose production should be continued. This correlates with my study.

SPECTRUM OF ILLNESSES:

Of the 153 patients included in this study, CNS diseases (32.7% - 50 cases), respiratory cases (22.2% - 34 cases) and infectious diseases (18.3% - 28) accounted for majority of cases.

This observation probably reflects the frequency of these diseases in our hospital and the pattern of our ICU admissions. Serum sodium abnormalities (both hyponatremia and hypernatremia) were found to be commonly associated with CNS diseases, 27.1% cases with hyponatremia and 25% cases with hypernatremia had infectious disease and gastrointestinal disease. A similar prospective study by S. Singhi etal[39], conducted at PGIMER where infectious disease (27%) were associated with hyponatremia. This correlates with my study. Whereas in a study by Subba Rao et al[2] 62% accounted for hyponatremia and 53% to hypernatremia, had either CNS or infectious disease. This could be due to the difference in pattern of PICU admissions in these studies. In a study by S. Singhi et al[39], only 10.3% of PICU admissions had CNS cases whereas in my study, 32.7% of PICU admissions had CNS disease.

In my study, hypokalemia was almost evenly distributed in diseases of various systems. A similar observation was made by S. Singhi and A. Marudkar[55] in a

descriptive analysis of 290 patient records. Another prospective study by S. Singhi et al[39], showed that approximately 50% of cases of hypokalemia occurred in patients with respiratory disease or gastrointestinal disease.

Hyperkalemia was found to be associated with CNS disease and respiratory diseases (both together constituting 70% of patients with hyperkalemia). This partly correlates with the observation made by S. Singhi et al[39], wherein he noticed that respiratory diseases and gastrointestinal diseases, together contributed to 46% of patients with hyperkalemia.

In my study, hypocalcemia was almost evenly distributed among infectious disease and respiratory diseases (both constituting 62% of patients with hypocalcemia). In a study by Zivin JR et al[113], concluded that hypocalcemia is extremely common in hospitalized patients and correlates with severity of illness, but not with a specific illness per se.

Hypercalcemia was seen in 46.7% patients admitted in PICU in my study. In other studies it was shown that severe hypercalcemia is frequently associated with neurological, gastrointestinal and renal diseases.

Hypochloremia was found to be associated with CNS, respiratory disease and infectious diseases.We are unaware of any other study on the prevalence of hyperchloremia or hypochloremia in the critical care setting.

Both hypoglycemia and hyperglycemia accounted for 50.2% and 46.2% cases with CNS disease.In a study by Krinsley et al[111], multivariable logistic regression analysis identified diabetes, septic shock, renal insufficiency, mechanical ventilation, severity of illness as independent risk factors for the development of hypoglycemia.

MORTALITY:

Patient who had hyponatremia, hypokalemia, hypochloremia at the time of admission to PICU were found to have a significantly higher mortality rate. A number of other studies showed similar observations. A prospective study of 727 children by S. Singhi et al[39], concluded that presence of severe hyponatremia is associated with a threefold increase in the risk of death. Another study by A. Dhawan and S. Singhi, also noticed a 3.5 times higher mortality in patients with hyponatremia when compared to those with normonatremia.

One descriptive, retrospective analysis by S. Singhi and A. Marudkar[55] and another study by S. Singhi et al; both showed a significantly higher mortality in patients with hypokalemia.

Of the 153 patients studied, only 1 patient expired and had mixed electrolyte abnormality at admission. The mortality rate was 0.7%. Similar observations were made in two other prospective studies by Subba rao et al[2] and S. Singhi et al[39].

MAINTENANCE FLUIDS:

In my study, use of DNS as maintenance fluid led to correction of the following electrolyte imbalances: Hypoglycemia, Hypernatremia, Hypercalcemia and use of RL as maintenance fluid led to correction of Hypercalcemia, Hyponatremia, Hyperglycemia.

In a study by Jingjing W, Erdi X, Yang feng X[76] it was shown that isotonic fluids are safer than hypotonic fluids in hospitalized children requiring maintenance IV fluid therapy. This corresponds with my study.

Another study by Rey C et al[114] also showed that hypotonic maintenance fluids increase the incidence of hyponatremia. Hence, isotonic maintenance fluids

should be considered as the standard maintenance fluids. This correlates with my study. Similar studies were done by Alexander B, Tom D and Montana et al.

A study by Choong K, Bohn D[115] concludes that maintenance fluid preparations should be individualized. No single intravenous solution is ideal for every child during all phases of illness, but there is evidence to suggest that the safest empirical choice is an isotonic solution. Hypotonic solutions should only be considered if the goal is to achieve a positive free water balance.

A study by Shamim[116] A mentioned that energy expenditure in critically ill children has been found to be as low as 50- 60 Kcal/Kg/day, by indirect calorimetric measurements. Fluid requirement is much less in critically ill children for a variety of reasons such as physical immobility, the use of muscle relaxants and sedatives, mechanical ventilation, and additional factors such as nonessential or facultative metabolism. Moreover, fluid requirement is further decreased because of inappropriate increase in arginine vasopressin which impairs the kidney's ability to excrete free water.

OUTCOME:

In this study, it was observed that the mortality rate and the relative risk of mortality increase with increase in the severity of mixed electrolyte imbalances. Study done by Subba Rao[2] and Thomas B also found high mortality rates in patients with mixed electrolyte abnormality when compared to those with single electrolyte abnormality. This corresponds with my study.

Similar observations were made by Shah GS, Das BK, Kumar S, Singh MK, Bhandari GP[20] and Singhi S, Gulati S, Prasad SVSS[24].

CONCLUSION

Fluid and electrolyte abnormalities in critically ill patients can lead to fatal consequences. More caution to electrolyte disturbances should be exercised in intensive care because it is often impossible to adequately assess symptoms and signs of critically ill patients. To provide optimal management, clinicians should be knowledgeable about fluid and electrolyte homeostasis and the underlying pathophysiology of the respective disorders. In addition, intensivists should pay attention to the administered fluid and medications potentially associated with fluid and electrolyte disturbances.

Mixed electrolyte abnormalities are highly prevalent in expired PICU patients.

In view of these facts, a routine estimation of serum electrolytes should be considered in all patients getting admitted to PICU.

Thus this study brings out the salient aspects of electrolyte abnormalities in severely ill children, and focuses on the importance and need to recognize the abnormalities and acts as good predictor of mortality in PICU.

Intravenous maintenance fluid therapy aims to replace daily urinary and insensible losses for ill children in whom adequate enteric administration of fluids is contraindicated or infeasible. The traditional determination of fluid volumes and composition dates back to Holliday and Segar's seminal article from 1957, which describes the relationship between weight, energy expenditure, and physiologic losses in healthy children. Combined with estimates of daily electrolyte requirements, this information supports the use of the hypotonic maintenance fluids that were widely used in pediatric medicine. However, using hypotonic intravenous fluids in a contemporary hospitalized patient who may have complex physiologic derangements, less caloric expenditure, decreased urinary output, and elevated antidiuretic hormone

levels is often not optimal; evidence over the last 2 decades shows that it may lead to an increased incidence of hyponatremia.

In our study it was revealed that, use of isotonic solution as maintenance fluid brought correction of electrolyte imbalance by 24 hours after admission. Hence, the study concludes that, administration of isotonic maintenance fluid is ideal for critically ill Pediatric patients.

SUMMARY

A prospective clinical study to study the electrolyte and blood glucose levels in children admitted in Pediatric ICU at admission and at the end of 24 hours, and to correlate above with fluids administered and outcome was conducted at our hospital from November 2015 to April 2017.

Fluid and electrolyte abnormalities are very common in critically ill patients and can lead to fatal consequences.Early goal directed therapy and a thorough understanding of common electrolyte abnormalities is necessary to ensure their correction.

Holliday-Segar equation remains the standard method for calculating maintenance fluid requirements.

Mixed electrolyte abnormalities are highly prevalent in expired PICU patients.Thus this study focuses on the need to recognize the electrolyte abnormalities and predict the mortality in PICU.

The ideal maintenance solution and fluid regimen remains a topic of heated debate in Paediatrics. A physiologically based framework for prescribing maintenance fluids is presented, with the objective of maintaining tonicity balance, and infusing the minimum volume of maintenance fluid required to maintain hemodynamics.

Our study results support the notion that isotonic maintenance fluid is safe in critically ill Pediatric patients.

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ETHICAL CLEARANCE

B.L.D.E.UNIVERSITY'S
SHRI.B.M.PATIL MEDICAL COLLEGE, BIJAPUR – 586103
INSTITUTIONAL ETHICAL COMMITTEE

NO/58/2015
20/11/15

INSTITUTIONAL ETHICAL CLEARANCE CERTIFICATE

The Ethical Committee of this college met on 17-11-2015 at 03pm scrutinize the Synopsis of Postgraduate Students of this college from Ethical Clearance point of view. After scrutiny the following original/corrected and revised version synopsis of the Thesis has accorded Ethical Clearance.

Title "Study of Serum electrolytes and blood glucose levels in children admitted to PICU and its co-relation with maintenance fluids and outcome"

Name of P.G. Student : Dr Keerthidarshini
Dept of paediatrics

Name of Guide/Co-investigator : Dr. S.S. Kalyanshettar, prof of paediatrics & Dr. B.B. Devaranavadagi, prof & HOD Biochemistry

DR.TEJASWINI VALLABHA
CHAIRMAN

CHAIRMAN
Institutional Ethical Committee
BLDEU's Shri B.M. Patil
Medical College,BIJAPUR-586103.

Following documents were placed before E.C. for Scrutinization:
1)Copy of Synopsis/Research Project
2)Copy of informed consent form.
3)Any other relevant documents.

INFORMED CONSENT FORM

BLDEU'S SHRI B. M. PATIL MEDICAL COLLEGE HOSPITAL AND RESEARCH CENTRE, VIJAYAPUR- 586103

TITLE OF THE PROJECT: **STUDY OF SERUM ELECTROLYTESAND BLOOD GLUCOSE IN CHILDREN ADMITTED TO PICU AND ITS CORRELATION WITH MAINTENANCE FLUIDS AND OUTCOME.**

PRINCIPAL INVESTIGATOR **:** Dr. KEERTHIDARSHINI

PG GUIDE **:** Dr. S S KALYANSHETTAR
PROFESSOR,
DEPARTMENT OF PAEDIATRICS

PG CO- GUIDE **:** DR. BASAVARAJ. DEVARNAVADAGI
PROFESSOR AND HOD,
DEPARTMENT OF BIOCHEMISTRY

CHAIRMAN ETHICAL COMMITTEE

All aspects of this consent form are explained to the patient attenders in the language understood by him/her.

I) **INFORMED PART**

1) PURPOSE OF RESEARCH:

I have been informed about this study. I have also been given a free choice of participation in this study.

2) PROCEDURE:

I am aware that in addition to routine care received I will be asked series of questions by the investigator. I have been asked to undergo the necessary

investigations and treatment, which will help the investigator in this study.

3) RISK AND DISCOMFORTS:

I understand that my child may experience some pain and discomfort during the examination or during treatment. This is mainly the result of my child's condition and the procedure of this study is not expected to exaggerate these feelings that are associated with the usual course of treatment.

4) BENEFITS:

I understand that my child's participation in this study will have no direct benefit to me other than the potential benefit of the treatment.

5) CONFIDENTIALITY:

I understand that the medical information produced by this study will become a part of hospital records and will be subject to the confidentiality and privacy regulation. Information of a sensitive personal nature will not be a part of the medical records, but will be stored in the investigator's research file and identified only by a code number.

If the data is used for publication in the medical literature or for teaching purpose, no name will be used and other identifiers such as photographs and audio or videotapes will be used only with my special written permission. I understand that I may see the photographs and videotapes and hear the audiotapes before giving this permission.

6) REQUEST FOR MORE INFORMATION:

I understand that I may ask more questions about the study at anytime. Dr. KEERTHIDARSHINI is available to answer my questions or concerns. I understand that I will be informed of any significant new findings discovered during the course of

the study, which might influence my continued participation.

If during the study, or later, I wish to discuss my participation in or concerns regarding this study with a person not directly involved, I am aware that the social worker of the hospital is available to talk with me. A copy of this consent form will be given to me to keep for careful reading.

7) REFUSAL OR WITHDRAWAL OF PARTICIPATION:

I understand that my participation is voluntary and that I may refuse to participate or may withdraw consent and discontinue participation in the study at any time without prejudice to my present or future care at this hospital. I also understand that Dr. KEERTHIDARSHINI may terminate my participation in the study after she has explained the reasons for doing so and has helped arrange for my continued care by my own physician or physical therapist, if this is appropriate.

8) INJURY STATEMENT:

I understand that in the unlikely event of injury to my child resulting directly from my participation in this study, if such injury were reported promptly, the appropriate treatment would be available to my child, but no further compensation would be provided. I understand that by my agreement to participate in this study I am not waiving any of my legal rights.

SIGNATURE OF PARENT/RELATIVE

NAME AND RELATION TO THE PATIENT

I have explained to shri/smt_____the purpose of the research, the procedures required and the possible risks and benefits to the best of my ability in patient's own language.

_____ _____

Dr. KEERTHIDARSHINI Date

(Investigator)

II) PARENTS CONSENT STATEMENT:

I confirm that Dr. KEERTHIDARSHINI has explained to me the purpose of research, the study procedures like collection of blood sample of my child for the estimation of blood glucose, serum sodium, potassium, calcium, phosphorus, RFT, LFT that my child will undergo, and the possible risks and discomforts my child may experience in my own understandable language. I have read and I understand this consent form. Therefore, I agree to give consent that my child may participate as a subject in this research project.

_____ _____

Participant / Guardian Date

_____ _____

Witness to signature Date

CASE PROFORMA

BLDE'S SHRI B.M.PATIL MEDICAL COLLEGE

HOSPITAL AND RESEARCH CENTRE, VIJAYAPUR

Name: **Case no:**

Age: **DOA:**

IP NO: **DOD:**

Sex:

Religion:

Residence:

Chief complaints:

COMPLAINTS	**Y/N**	**DURATION**
Any other		

Past History: Significant/Insignificant, if significant specify.

History of immunization: complete/Incomplete, if incomplete specify

Personal History:

Diet-

	CALORIE	PROTEIN
INTAKE		
EXPECTED		

Family History:Significant/Insignificant ,if significant specify.

Past Treatment History:Significant/Insignificant, if significant specify.

General Physical Examination

Anthropometry :

	Actual	Expected	Comments
Height/length	:		
Weight	:		
Head circumference	:		
Chest circumference	:		
Mid arm circumference	:		
US/LS Ratio	:		

Vitals

	ABNORMAL	TIME AFTER ADMISSION	DURATION
PR			
RR			
BP			
SPO2			
TEMPERATURE			

Head to toe examination:

HEAD	
NECK	
CHEST	
UPPER LIMB	
ABDOMEN	
LOWER LIMB	
SKIN	
OTHERS	

SYSTEMIC EXAMINATION.

- Respiratory System-normal/abnormal , specify if abnormal
- Cardiovascular System-normal/abnormal, specify if abnormal
- Central Nervous System-normal/abnormal, specify if abnormal
- Per abdomen-normal/ abnormal, specify if abnormal.

INVESTIGATIONS:

HAEMATOLOGY:–

INVESTIGATIONS	AT ADMISSION	AT 24 HOURS OF ADMISSION
Haemoglobin	gm %	gm %
Total WBC counts	Cells/mm^3	Cells/mm^3
Differential counts -		
Neutrophils	%	%
Lymphocytes	%	%
Eosinophils	%	%
Monocytes	%	%
Basophils	%	%
ESR	mm after 1 hour	mm after 1 hour
PLATELET COUNT	Lakhs/mm^3	Lakhs/mm^3
S.Na+	**mEq/l**	**mEq/l**
S.K+	**mEq/l**	**mEq/l**
S.Ca+	**mg/dl**	**mg/dl**
S.Cl-	**mg/dl**	**mg/dl**
Blood glucose	**mg /dl**	**mg/dl**
RFT		
LFT		

REMARK: Comment if abnormal any other time.

Chest X-ray (If done):

Course in PICU:

Type of maintenance fluid used :

Outcome death/ discharge/ any other specify:

Ventilator support-required/ not required-if required then duration:

Duration of PICU stay:

Complications: **day of illness** **duration**

FINAL DIAGNOSIS

TREATMENT GIVEN

KEY TO MASTER CHART

Sl no	-	serial number
IP no	-	Inpatient number
GRBS	-	Glucose random blood sugar
POT	-	Potassium
CAL	-	Calcium
CHLOR	-	Chloride
IVF	-	Intravenous fluid
adm	-	Admission
Y	-	Years
mo	-	Months
F	-	Female
M	-	Male
Tb	-	Tuberculosis
LRTI	-	Lower respiratory tract infection
CP	-	Cerebral palsy
OP	-	Organophosphorous poisoning
CHD	-	Congenital heart disease
AGE	-	Acute gastroenteritis
CSOM	-	Chronic suppurative otitis media
GBS	-	Guillian barre syndrome
CHPS	-	Congenital hypertrophic pyloric stenosis
LOS	-	Late onset sepsis
FL	-	Flusodex (0.45% DNS)

EP	-	Isolyte P
RL	-	Ringers lactate
DNS	-	Dextrose normal saline
DIS	-	Discharge
CVS	-	Cardiovascular system
RS	-	Respiratory system
GIT	-	Gastrointestinal system
CNS	-	Central nervous system

MASTER CHART

sl no	IP	NAME	AGE	SEX	DIAGNO	GRBS	GRBS	SODIUM	SODIUM	POT	POT	CAL	CAL	CHLOR	CHLOR	IVF	OUTCOME	system involved
						adm	24hours	adm	24hours	adm	24hours	adm	24hours	adm	24hours			
1	108	Ishwar	5y	m	tb meningitits	120	98	128	133	3.8	4.4	9.6	8.8	92	92	FL	Dis	CNS
2	1744	Darshan	10y	m	snake B	78	73	137	138	4.4	3.5	11	8.8	96	95	FL	Dis	CNS
3	3487	Amruta	3mo	f	LRTI	76	92	137	139	5	5.1	10	11	98	98	EP	Dis	RS
4	3692	Renuka	13y	f	seizures	198	124	139	142	4.5	3.6	10.6	10	101	102	DNS	Dis	CNS
5	3783	Deepika	7y	f	CP	107	103	132	137	2.9	3.9	9.5	9.4	90	96	FL	Death	CNS
6	3793	Bhagyash	1y	f	viral en	374	96	140	144	4.2	4.2	10.5	9.7	97	102	FL	Dis	CNS
7	3790	Chinnu	1y2mo	f	kerosene	132	110	138	137	4.3	4.3	10.6	10.7	100	98	FL	Dis	RS
8	3969	Ganesh	6mo	m	LRTI	140	102	137	138	4.7	4	10.1	10.1	100	96	FL	Dis	RS
9	4541	Rihan	8y	m	post dipth	98	110	131	136	5.7	4.1	10.5	10.2	98	94	FL	Dis	RS
10	4679	Akshay	2mo	m	septic shock	444	450	149	135	3.7	5.2	10.8	11.8	112	99	EP	Dis	CVS
11	5390	Malleshi	12y	m	op	119	102	142	138	3.6	3.5	10.2	9.8	105	99	FL	DIS	GIT
12	5391	Malkapp	10y	m	op	94	96	141	140	3.7	3.7	9.9	9.9	105	101	FL	Dis	GIT
13	5522	santosh	14mo	m	croup	135	110	135	136	4.7	4.4	10.1	10.8	91	91	FL	DIS	RS
14	5559	Samarth	3mo	m	CHD	71	132	143	135	5	3.3	10.7	10	89	89	EP	DIS	CVS
15	5602	shivram	7mo	m	seizures	105	127	142	140	4.7	4.1	11	11	98	102	FL	dis	CNS
16	5641	praveen	1y	m	castor	182	98	139	136	4.8	5.2	11.8	11.2	98	95	EP	DIS	GIT
17	5895	shravan	7mo	m	dengue	110	76	135	138	4	3.5	9	8.4	100	99	RL	DIS	CVS
18	5915	NAGU	2y	m	snake B	81	208	139	135	4	4.5	10.1	9.6	100	96	FL	DIS	CNS
19	5932	shradha	5mo	f	meningiti	71	81	130	135	6	4.8	9.2	9.4	90	98	FL	Dis	CNS
20	6679	abhishek	10y	m	consoli	112	95	129	137	2.8	3	6.7	8.4	95	96	dns	dis	RS
21	6432	aditya	13mo	m	lrti	116	94	135	139	4.2	5.1	10	10.3	95	95	FL	DIS	RS
22	6906	POOJA	4Y	F	MALARIA	182	298	130	133	3.5	3.3	9	8.7	91	95	FL	DIS	INFECTIOUS
23	7482	sampat	2y	m	drowning	138	80	135	138	3.7	3.7	10.3	9.5	95	96	FL	DIS	CNS
24	6099	KUSHAL	4Y	m	benzodiaz	85	91	132	132	3.5	5.9	10.5	10.9	93	90	FL	DIS	GIT
25	6896	sevanti	10y	f	pneumonia	123	98	130	134	3	2.5	8.7	8.3	92	95	DNS	DIS	RS
26	8490	Nivedita	12y	f	AGE	102	110	143	140	3.9	4.4	10.4	9.5	110	102	FL	DIS	GIT
27	8189	Irfanaaz	7m0	f	pneumonia	156	100	134	136	5	5	9.3	9.2	96	93	EP	DIS	RS
28	8451	shreen	8y	f	mumps	129	110	143	138	3.6	3.7	9.2	9.2	101	100	FL	DIS	CNS
29	10094	ATIYA	4MO	F	laryngomal	135	101	138	130	5	5.9	8	10.5	94	93	EP	DIS	RS
30	17039	satappa	4y	m		124	78	138	135	4	4.4	8.9	9	99	97	FL	dis	CNS
31	19619	muktesh	9y	m	dengue	110	76	140	140	4	4.3	8.1	9.5	104	98	RL	dis	INFECTIOUS
32	20016	basavaraj	14y	m	CSOM	128	98	143	141	4	4.1	10.1	9.6	107	106	fl	dis	CNS
33	20032	laxmi	12y	f	CHD	110	70	136	145	4.9	4	9	9.8	102	101	fl	dis	CVS
34	24399	laxmi	4y	f	lrti	135	98	136	137	5.3	2.8	8.6	8.4	100	99	fl	dis	RS
35	27331	archit	15mo	m	bronchopneumonia	222	106	144	138	5.2	4.7	8.9	8.4	88	91	EP	dis	RS
36	28850	abhi	2mo	m	lrti	110	60	136	138	4.8	4.7	7.7	8	76	88	EP	dis	RS
37	28993	saanvi	11mo	f	dengue encephalopathy	32	74	168	158	2.9	2.4	8.9	8	110	113	ep	dis	INFECTIOUS

38	27800	amasidda	11y	m	GBS	172	110	141	138	4.2	4.7	9.3	9.8	94	93	FL	dis	CNS
39	29202	rohan	8mo	m	viralhemorrhagic fever	110	121	136	139	2.3	4.6	9.8	8.4	95	97	rl	dis	INFECTIOUS
40	28973	siddarth	2y	m	dengue	119	70	138	141	4.5	4	9.8	8.6	95	95	fl	discharge	INFECTIOUS
41	31179	anand	3y	m	viral hemorrhagic fever	155	102	128	133	5.4	5	8.7	9	78	90	fl	dis	INFECTIOUS
42	31864	laxmi	6mo	f	seizures	130	78	137	138	4	4.2	7.3	8.1	102	94	ep	dis	CNS
43	32200	preetam	8y	m		100	106	131	133	4.4	4.6	9.2	9	87	87	dns	dis	CNS
44	32831	sanjana	6y	f	meningitis	161	60	136	130	3.7	4	10.9	8.8	91	86	fl	dis	CNS
45	32736	siddarth	4y	m	seizures	111	73	131	132	4	3.7	9.9	8	92	93	FL	dis	CNS
46	33135	soujanya	2y	f	scorpion sting	149	58	142	135	4	3.4	9.7	8.2	98	95	RL	dis	CVS
47	33115	shivaprabhugouda	5y	m	lrti	94	62	139	131	4	3	8.4	7.8	94	90	fl	dis	RS
48	33213	bhuvana	4y	f	?kawasaki	112	62	136	135	4.5	4.6	10.3	9.4	96	95	fl	dis	INFECTIOUS
49	33548	prerana	1y	f	dengue fever	106	78	138	134	3.3	3.1	8.9	9	94	95	dns	dis	INFECTIOUS
50	33710	rohit	3y	m	rickettsia	160	62	133	131	5.4	4.5	8.3	8.2	90	88	ep	dis	INFECTIOUS
51	6	prashant	5y	m	acute febrile illness	19	120	138	135	4.6	3.6	8.9	8.5	105	100	fl	dis	INFECTIOUS
52	434	b/o laxmi	3mo	f	CHPS	76	108	135	127	5.3	6.4	10.8	11	100	86	EP	DIS	GIT
53	2549	YODA	18MO	F	seizures	431	99	140	148	5.1	6	11.3	10	100	100	FLUSODEX	DIS	CNS
54	5657	prateeksha	2y	f	chd	118	92	138	136	4.9	3.5	9.9	9.5	97	92	fl	dis	CVS
55	33866	karthik	14y	m	neurocysticercosis	119	76	135	134	4	4.3	9.2	9.2	95	94	fl	dis	CNS
56	33957	shrishail	11y	m	snake B	427	120	135	134	3.5	3.6	8.3	9	96	97	fl	dis	CNS
57	34840	sabina	14y	f	rat poison	417	67	144	139	3.6	3.7	9.3	8.9	102	99	fl	dis	GIT
58	35017	shreya	13mo	f	acute ge with mod deh	108	86	141	135	3.2	4.2	9.1	9	102	103	ep	dis	GIT
59	35012	deepak	2y	m	kerosene	143	278	134	136	4.2	6	9	9.1	95	98	ep	dis	RS
60	35224	sinchana	18mo	f	viral fever	100	130	135	131	4.6	4.2	10.2	9	95	94	rl	dis	INFECTIOUS
61	35194	vidya	6y	f	viral fever	97	109	142	139	3.4	3	9.1	8.1	95	99	rl	dis	INFECTIOUS
62	35231	fayaz	6y	m	diphtheria	78	76	131	135	3.9	3.3	9.1	9.2	99	92	fl	dis	RS
63	35244	suma	2y	f	seizures	138	88	136	135	3.7	4.4	8.6	8.8	96	98	fl	dis	CNS
64	35275	samarth	6y	m	viral hemorrhagic fever	130	76	132	134	4.3	4.2	8.2	8.8	91	95	dns	dis	INFECTIOUS
65	35274	shivangouda	8y	m	dengue	140	124	133	133	4.4	4.1	8.4	7.6	94	93	dns	dis	INFECTIOUS
66	35263	prajwal	7y	m	diphtheria	129	58	132	131	3.8	3.5	9	8.4	91	89	fl	dis	RS
67	35433	chandu	14mo	m	hemolytic anaemia	181	102	133	137	4.2	4.2	9.6	10.1	102	99	ep	dis	GIT
68	4276	baliram	10y	m	chronic SDH	156	98	138	136	5	4.3	10.9	10.7	95	98	fl	dis	CNS
69	7079	preetu	1y	m	infantile tremor synd	108	72	138	139	3	3	10.3	9.9	97	97	fl	dis	CNS
70	7651	yuvraj	9y	m	drowning	98	64	131	140	3.3	4	10.3	9.8	90	103	fl	dis	CNS
71	35361	soujanya	1y	f	seizures	188	60	132	137	4.2	4.2	8.7	9.2	94	109	fl	dis	CNS
72	35550	pratiksha	4y	f	pleural effusion	133	80	136	133	4.5	4	8.8	8	100	96	fl	dis	RS
73	8053	archana	5mo	f	septic shock	132	263	141	131	4.8	4.8	9	7.5	97	92	ep	dis	INFECTIOUS
74	29646	arbaz	4y	m	phenol poisoning	120	100	146	140	3.8	3.9	9.1	9	103	99	fl	dis	GIT
75	9530	hanipa	18m0	f	foreign body asp	102	98	140	130	4.7	3.5	10.2	9.3	101	95	fl	dis	RS
76	9634	dhaniyal	10mo	m	febrile seizures	130	110	137	137	3.9	4.8	9.8	10.8	99	98	ep	dis	CNS
77	36094	manjunath	6mo	m	acute ge with severe dehy	106	205	131	144	2.2	5.9	8.1	8.2	89	104	fl	dis	GIT
78	36082	swaroop	7mo	m	acute ge with mod deh	139	87	132	138	3.7	4.5	9.1	9.6	95	95	ep	dis	GIT
79	35766	alina	2y	f	acute ge with paralytic ileus	95	78	135	135	4.5	4.6	9.1	8.7	100	95	fl	dis	GIT

80	36077	brinda	8m0	f	acute ge with mod deh	89	95	134	136	4.8	5.1	9.8	9.4	95	97	fl	dis	GIT
81	36260	shivanand	7mo	m	acute ge with severe dehy	150	92	145	141	3.9	3.3	10	8	102	97	ep	dis	GIT
82	36561	laxmi	8y	f	rickettsia	178	78	131	131	4.1	3.9	8.1	8.9	89	93	rl	dis	INFECTIOUS
83	36314	saraswati	1y	f	acyte ge with severe dehyd	80	87	139	130	4.4	4.3	9.5	9.1	100	95	ep	dis	GIT
84	36744	amogh	11y	m	viral hemorrhagic fever	100	109	132	139	4.2	3.7	8.8	8.9	93	99	rl	dis	INFECTIOUS
85	36829	sangamesh	4mo	m	lrti	135	89	133	132	5.2	4.1	9.8	8.1	93	91	ep	discharge	RS
86	36877	fayaz	18m0	m	poisoing	102	115	140	132	4	4.2	8.8	9.5	103	94	fl	dis	GIT
87	37440	ashwini	11y	f	lrti	45	197	137	134	4.8	3	8.9	7.5	107	91	fl	dis	RS
88	36957	siddarth	1y	m	seizures	60	85	150	135	4.2	5.3	7.7	9.2	114	97	ep	discharge	CNS
89	37488	shrishail	16mo	m	febrile seizures	208	74	135	139	4.6	5	10.2	9.5	92	95	fl	discharge	CNS
90	37750	aditya	9y	m	febrile seizures	152	104	131	130	3.7	3.7	9	8.3	85	90	fl	dis	CNS
91	37829	pallavi	7y	f	enteric fever	72	100	129	131	3.6	4.8	7.8	7.2	90	90	fl	dis	INFECTIOUS
92	37755	ashwini	2mo	f	LOS	89	95	133	131	5.2	5.7	9.9	10.6	96	95	ep	dis	INFECTIOUS
93	38329	pragati	5y	f	seizures	111	72	137	133	4.3	4	8.2	8.4	104	89	fl	dis	CNS
94	38514	ramesh	11mo	m	acute ge with severe dehy	73	82	137	137	3.7	6	8.9	6.6	94	102	fl	dis	GIT
95	38720	kedar	2y	m	febrile seizures	169	75	137	134	4.2	3.6	10	9.3	93	94	fl	dis	CNS
96	39000	preetam	45days	m	bronchopneumonia	74	80	134	131	5.7	5.4	10	9.4	94	94	ep	discharge	RS
97	39110	ramesh	12y	m	diphtheria	116	100	131	136	5.4	4.1	9.4	8.5	94	96	fl	discharge	RS
98	39770	sharath	7mo	m	viral meningitis	152	100	136	136	5.5	5.9	9.7	10.4	95	97	ep	dis	CNS
99	39811	ashok	10y	m	pneumonia	86	78	136	133	3	2.6	7.7	8	92	92	fl	discharge	RS
100	39765	nagamma	3y	f	op	405	102	134	139	3.6	3.1	9	9	92	99	fl	dis	GIT
101	40862	manveet	2mo	m	seizures	104	309	133	130	5.3	4.6	9.1	9.2	97	93	ep	dis	CNS
102	40948	chandana	4y	f	bronchopneumonia	102	75	133	131	3	3.1	8	7.6	93	92	fl	dis	RS
103	42527	sravani	6y	f	head injury	116	95	130	138	3.9	4	8.9	9	95	99	fl	dis	CNS
104	42597	md.samad	8mo	m	febrile seizures	167	149	132	137	4.2	5.1	8	8.9	94	96	ep	dis	CNS
105	808	aishwarya	10y	f	cerebral abcess	119	135	146	138	4.5	7	9.6	8.8	101	99	fl	dama	CNS
106	7	parvati	14y	f	snake B	116	120	139	123	4.1	3.9	8.8	8	101	99	fl	dama	CNS
107	1104	soujanya	30mo	f	tb	122	72	131	142	4	4	10.5	9.8	90	101	FL	dis	RS
108	2830	radhika	5y	f	pleural effusion	130	77	136	136	3.4	4.8	7.9	8.2	91	90	fl	dis	RS
109	2944	samarth	3y	m	lrti	130	86	136	136	5.3	4.7	8.5	8.7	93	93	fl	dis	RS
110	9398	pavitra	7y	f	pneumonia	83	132	135	140	4.1	2.7	9.3	7.7	90	96	fl	dis	RS
111	7734	ashwini	14y	f	severe nutritional anaemia	163	110	140	132	4.3	3.9	7.3	8	101	95	fl	dis	HEMAT
112	9572	laxmi	8y	f	scorpion sting	103	91	152	139	3.6	3.4	10.8	8.4	104	100	fl	dis	CVS
113	9610	shravani	2y	f	seizure disorder	92	99	142	139	5.6	5.4	10.3	9.7	106	104	ep	dis	CNS
114	9525	samarth	3mo	m	seizure disorder	87	62	140	136	5.6	5.8	11.2	10.6	105	102	ep	discharge	CNS
115	10141	b/omehboobi1mo	1mo	m	lrti	116	123	137	145	6	5.8	10.7	10.5	95	99	ep	dama	RS
116	10034	Bhagyash	10y	f	acute infarct	260	94	130	138	3.4	3.4	8.9	8.6	101	102	DNS	discharge	CNS
117	10186	raghav	11m0	m	seizure disorder	104	80	145	140	5.1	4.3	10.9	11.1	110	109	ep	discharge	CNS
118	10307	deepa.	5y	f	scorpion sting	100	85	145	145	4.5	3.9	9.6	9.3	100	108	fl	dis	CVS
119	10180	megha	30mo	f	typhoid	99	83	148	148	4.3	4.3	8.9	9.5	115	112	rl	dis	INFECTIOUS
120	10935	sravan,	8mo	m	acute ge with severe dehy	368	172	146	136	3.1	5	9	9.8	106	95	NS	DAMA	GIT
121	11328	aruna	3y	f	rickettsia	94	98	132	139	2.6	2.3	8.8	8.1	92	108	fl	dis	INFECTIOUS

122	11465	ayan	10y	m	op	105	82	145	145	2.9	4.2	11	10.8	110	102	fl	dis	GIT
123	11466	trisha	5y	f	op	204	98	146	139	3.3	3.3	10.3	9.2	114	105	fl	dis	GIT
124	14136	nikita	14y	f	phenol poisoning	107	100	142	141	4.7	4.3	9.4	9	106	105	dns	dis	GIT
125	13738	siddaraya	7y	m	parotitis	104	84	139	140	4.2	4.1	9.8	8.8	99	102	dns	dis	INFECTIOUS
126	14532	shravani	2y	f	pneumonia	100	126	138	139	4.6	4.7	9.6	9	102	97	ep	dis	RS
127	14892	manish	9y	m	dengue	140	75	135	134	3.7	3.7	8.1	8.1	99	104	rl	dis	INFECTIOUS
128	14680	parasu	1mo	m	chd	116	76	135	142	6.8	3.5	10.2	9.9	95	100	ep	dis	CVS
129	14302	basamma	13y	f	meningitis	168	266	153	145	3.6	3.4	8.1	8	118	113	fl	dis	CNS
130	14973	bindushree	1y	f	ac febrile illness	102	98	131	137	4.4	4.8	8	9.9	101	101	ep	dis	INFECTIOUS
131	15222	girish	11y	m	acute ge	82	90	140	141	4.3	4.3	9.6	9.2	106	110	rl	dis	GIT
132	11566	varun	12y	m	dengue	124	107	133	143	5.4	3.2	8.5	8	90	102	rl	dis	INFECTIOUS
133	11482	shankarlinga	12y	m	meningitis	124	100	145	137	5.2	3.8	8.8	8.2	105	100	dns	dis	CNS
134	15019	pradnya	4y	f	acute ge	110	103	138	138	6.3	3.6	9.7	9	93	93	rl	dis	GIT
135	15883	deepa	11y	f	benzodiaz	190	130	145	145	3.8	3.6	8.9	8.6	112	113	dns	dis	GIT
136	18083	sanket	1mo	m	chps	108	78	131	143	4.8	4.7	12	10.7	84	95	ep	dis	GIT
137	18810	savitri	14y	f	hysterical hyperventilation	103	142	136	137	4.5	4.7	9	9	96	103	dns	dis	CNS
138	18620	basavaraj	11mo	m	acute ge	90	89	133	142	6.8	3.1	8.2	9.6	100	105	rl	ama	GIT
139	17229	sadbodanand	10y	m	hypocalcemic tetany	150	254	135	133	4.8	3.4	8.2	8.5	98	101	fl	dis	CNS
140	18106	tanuja	2y	f	intussusception	197	88	141	135	5	4	9.9	8.5	99	100	rl	dis	GIT
141	18213	chetan	2y	m	empyema	116	88	136	136	3.6	4.1	8.2	8.4	101	100	fl	dis	RS
142	16948	akshata	12y	f	viral fever	99	102	143	137	4.4	4.2	7.9	8.8	97	100	rl	dis	INFECTIOUS
143	20356	yashwant	5y	m	viral encephalitis	312	353	138	140	5	4.6	7.8	9	96	94	fl	dis	CNS
144	24445	sahana	13y	f	dengue	103	96	135	144	4.4	3.7	8.6	8.5	94	99	rl	dis	INFECTIOUS
145	24619	impana	4y	f	dengue	88	80	131	140	4.3	4.1	8.7	9	95	94	rl	dis	INFECTIOUS
146	24198	sharath	8mo	m	severe anemia	119	398	130	133	3.8	4.2	9	9.8	100	94	fl	dis	HEMAT
147	23035	iramma	10y	f	snake B	340	97	146	142	3.6	4.2	10.6	8.6	103	102	rl	dis	HEMAT
148	24362	abhishek	3y	m	hypoglycemic attack	52	79	135	141	4.1	3.4	9.1	9.5	96	100	dns	dis	CNS
149	24367	abhishek	7y	m	tonsillitis	77	74	140	140	4.4	3.5	9.4	9	92	94	fl	dis	RS
150	24143	md.abdullah	50days	m	acute subdural hemorrhage	65	114	142	141	5.9	3.7	10.5	9.4	95	98	ep	dis	CNS
151	24686	shantagouda	6y	m	GBS	105	129	133	140	4.4	4.7	9.9	9.6	93	100	fl	dis	CNS
152	24642	shravani	1y	f	lrti	277	189	149	153	5	4.3	8.3	8.6	102	111	fl	dis	RS
153	24902	nagaraj	2y	m	viral encephalitis	161	337	129	130	4.3	2.7	8.9	7.8	94	97	fl	dis	CNS