The Ion Potassium

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INTRODUCTION

Modern anesthesia bears a close relationship to the scientific world which surrounds us. The formulae for anesthetic agents and drugs are becoming more complex as halogens and electrolytes are introduced into the field of anesthesia.

Cognizance of the existence of such agents and drugs is not enough. A basic understanding of the theories regarding the physical and chemical properties of the matter with which we deal is important.

The subject presented here concerns one small, but very important entity in the vast expanse of known facts and theory — the potassium ion. An endeavor will be made to explain the part that the potassium ion plays in the body and the importance of it in anesthesia.

Anesthesia, just as in any other scientific field, is constantly in a state of transition. The anesthetist must go forward with knowledge of new techniques and procedures. In this field there is no room for those who resist change, for here, we are dealing with human lives. Scientists are working constantly to provide newer and safer agents and supporting drugs for anesthetic purposes. It is the responsibility

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<thead>
<tr>
<th>ELECTROLYTE CONSTITUENTS OF BODY FLUIDS</th>
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<tbody>
<tr>
<td><strong>CATIONS</strong> (+)</td>
</tr>
<tr>
<td>Sodium (Na+)</td>
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<tr>
<td>Potassium (K+)</td>
</tr>
<tr>
<td>Calcium (Ca++)</td>
</tr>
<tr>
<td>Magnesium (Mg++)</td>
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<tr>
<td><strong>ANIONS</strong> (−)</td>
</tr>
<tr>
<td>Bicarbonate (HCO₃⁻)</td>
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<tr>
<td>Chloride (Cl⁻)</td>
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<tr>
<td>Phosphate (HPO₄⁻)</td>
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<td>Sulfate (SO₄⁻)</td>
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<tr>
<td>Organic acids (Org. Ac.)</td>
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<td>Proteinate (Pr.)</td>
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of the anesthetist to know which agents are available and the circumstances that warrant their use.

Figure 1 illustrates, from a chemical standpoint, the electrolyte constituents of body fluids. The soluble inorganic constituents of body fluids are present in the ionized state. The body ions are divided into cations and anions. Cations exist as potassium, sodium, calcium, and magnesium, while anions are bicarbonate, sulfate, phosphate, chloride, bromide, and iodide. Mixtures of the cations and anions are referred to as electrolytes. 1

Body fluid is present in two main categories: (1) intracellular fluid, which is found within tissue cells, and (2) extracellular fluid such as plasma, lymph, and interstitial fluid. (Figure 2)

The principal basic ion of the body cells is potassium. 2 It is the chief cation of intracellular fluid and is present in a high concentration. No other ion can functionally replace it. The existence, integrity, and survival of the cell are dependent on an adequate potassium level. Potassium is important in many physiological processes and is found abundantly in nerve and muscle tissue. It is essential to the maintenance of the heartbeat and in neuromuscular transmission. It is also necessary for the proper functioning of acetylcholine. Lack of potassium at the myoneural junction results in inability of the muscle to contract. 3

The ion is also found in extracellular fluid but in a much lower concentration. Here, sodium is the main cation.

Absorption: Potassium ions are readily absorbed from the intestinal tract and parenteral sites of administration. The ion influences osmotic pressure, acid-base balance and water retention. Much of it is removed by the liver and gradually liberated into the blood. Skeletal and cardiac muscles play an active part in the uptake of potassium ions and the cell provides a buffer system whereby an ex-

![Figure 2: Diagram of Body Fluids](image-url)
cessive concentration of extracellular potassium is prevented. Otherwise, any administration of the ion could result in toxicity.\(^3\)

**Excretion and Measurement:** Excretion of the potassium ion is accomplished chiefly by the kidneys. Normally about 100 mEq. of potassium are ingested daily and an equivalent amount must be excreted to maintain a normal balance. A milliequivalent, which is the measurement used for electrolytes, deals with charges, not mass, and is computed by dividing the atomic weight of the element by the number of its valence.\(^4\)

**Metabolism:** The metabolism of potassium is altered by either a deficiency or an excess of the ion. Excessive loss from either the gastrointestinal tract or the kidneys leads to a negative balance or deficiency which is called hypokalemia. Loss of potassium from the gastrointestinal tract is caused by severe diarrhea, vomiting, pyloric stenosis, ulcerative colitis, or bowel obstruction in which potassium has escaped into the lumen of the bowel.

Loss of potassium from the kidneys may be a result of Cushing’s disease, steroid therapy, in which there is accelerated excretion of K\(^+\), diuretics, diabetic acidosis, in which K\(^+\) leaves the cell and is excreted, renal acidosis, infusion of large amounts of NaCl solutions, or cellular dehydration.

A positive potassium balance or excess results from decreased urinary excretion of the ion and is called hyperkalemia. Hyperkalemia may occur as a result of: Adrenal insufficiency in which the renal mechanism for the excretion of K\(^+\) is impaired; diseases of the kidney which impair urine excretion; crushing accidents where muscles are damaged and a large amount of the ion is collected in the extracellular fluid.\(^3\)

Low potassium levels are more common than excesses. Symptoms which may indicate low levels include lassitude, loss of muscle tone, failure of myoneural conduction and irregularities of cardiac muscle tone.

High concentrations of potassium exert their main effect on the heart. Arrhythmias, heart block and cardiac arrest can all result from a high extracellular potassium level.

The use of the potassium ion should always be considered in the emergency patient if reasonable renal function exists. Definite contraindications to the use of potassium include untreated renal insufficiency, renal failure or temporary renal shut-down.

The effects of potassium on the body systems are illustrated in Figure 3.

**Circulatory System:** Potassium has a dual action on the heart. It affects impulse conduction and muscle contractility. Extracellular potassium ion is necessary for normal cardiac function. Absence of the ion causes the heart to stop beating in systole and the heart will not respond to vagal stimulation.

An excess of the ion will cause the heart to stop beating in diastole, due to depression of the myocardium.\(^3\)

**Nervous System:** No effect of the potassium ion is seen in the higher cerebral centers of the central nervous system. It stimulates pain receptors of the sensory nerves. Potassium causes muscle excitation and contraction. It also initiates muscle contraction due to membrane depolarization. Potassium helps to re-establish myoneural...
transmission by aiding the action of acetylcholine, and it helps to overcome the block at the myoneural junction produced by nondepolarizing relaxants such as curare.

Excretory System: Potassium is excreted by the kidney. Renal exchange involves the exchange of potassium with sodium in the renal tubule.

Endocrine System: The adrenal cortical hormone, desoxycorticosterone (DOAC), a mineralo-corticoid, governs the metabolism of salts and water. In the process sodium is retained and potassium is excreted. Adrenal cortical insufficiency results when potassium is retained and sodium and water are excreted.

Respiratory System: In normal respirations, potassium plays an active part in the chloride shift. In the form of potassium bicarbonate, potassium is ionized into $K^+$ ions and $HCO_3^-$ ions. The cell membrane is permeable to negative ions but not to positive ions, therefore, $HCO_3^-$ is permitted to leave the cell but $K^+$ ions are retained intracellularly.
Digestive System: Intestinal fluids contain approximately 10 mEq/Liter of potassium, but losses from the gastrointestinal tract continue to occur in spite of potassium intake.

The most accurate way to determine the existence of cellular K+ is to measure the potassium intake against urinary output. The most accurate way to determine the existence of cellular K+ is to measure the potassium intake against urinary output.4

VARIATIONS OF POTASSIUM WITH DISEASE (FIGURE 4)

Potassium is directly involved in several adverse conditions which affect the blood level. Anemia results when the K+ level is below normal, due to a decrease in cell volume. In bowel obstruction an increase in serum potassium occurs. Addison’s disease results in increased potassium due to decreased adrenal function. Respiratory acidosis results when the myocardium absorbs potassium. Carbon dioxide excess stimulates the sympathico-adrenal system and potassium is released by the liver. An excess of potassium released in this process can cause cardiac arrest.1

EFFECTS OF POTASSIUM DURING ANESTHESIA

Potassium may have adverse effects during anesthesia. Alterations of potassium levels occur during general anesthesia. Concentration of the potassium ion is influenced by respiratory acidosis, which may occur during anesthesia. A recent theory is that changes in serum potassium are di-

<table>
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<tr>
<th>NORMAL K LEVEL: 3.8 - 5.6 Meq/l</th>
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<tr>
<td>ABNORMAL K LEVELS</td>
</tr>
<tr>
<td>HYPOKALEMIA: below 3.8 Meq/l</td>
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<tr>
<td>PR interval ↑</td>
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<tr>
<td>ST segments ↓</td>
</tr>
<tr>
<td>T waves ↓</td>
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<tr>
<td>U waves prominent</td>
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<tr>
<td>HYPERKALEMIA: 7 Meq/l</td>
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<tr>
<td>Tall-peaked T waves leading to atrial standstill as Serum K increases</td>
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<tr>
<td>VENTRICULAR FIBRILLATION: 12 Meq/l</td>
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<tr>
<td>Rapid rate</td>
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<td>Irregular rhythm may terminate in asystole</td>
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<tr>
<td>CARDIAC ARREST: will follow ventricular fibrillation</td>
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FIGURE 4
directly related to carbon dioxide retention which in turn causes respiratory acidosis. Abrupt removal of the carbon dioxide causes a rapid rise in serum potassium and the result can be ventricular fibrillation.\(^1\)

**POTASSIUM AND CURARE**

Potassium can be an effective antagonist to muscle relaxants such as curare. Sodium and potassium are found in myoneural tissues — potassium in the intracellular fluid and sodium in the extracellular fluid. Neuromuscular activity is associated with the outward diffusion of sodium. During muscle recovery the action is reversed. At rest the potassium concentration is maintained despite the gradients that are established by each ion on their respective sides of the membrane. When potassium chloride is given, the muscles and nerves contract, and this results in depolarization and the release of acetylcholine. The potassium ion is therefore an antagonist to curare, since it precipitates the release of acetylcholine which antagonizes curare.\(^1\) Potassium ions also effectively antagonize the effects of calcium.

**POTASSIUM AND EMERGENCIES**

Anesthetists are often faced with the responsibility of administering adequate and safe anesthesia to the emergency patient when surgery must be performed either to prolong a life or to save a life.

Emergency patients can be divided into two groups. First, there is the chronically ill patient who faces emergency surgery. Such patients are those with diabetes, cardiac, kidney, or lung disease, endocrine disorders, anemias, neuromuscular disturbances, malignancies and bowel obstruction. The second group may have acute conditions resulting from crushing accidents, burns, bowel obstructions, hemorrhage or shock.

However different these conditions may seem, they usually share one common factor — electrolyte imbalance which involves an upset in potassium metabolism.

It is the responsibility of the anesthetist to know that this situation can exist, the problems it presents and the measures that are available to combat it.

In choosing an anesthetic agent for the emergency patient with a chronic disease, careful consideration must be given. These patients are often acidotic and already have an electrolyte imbalance. If the patient is very debilitated, a local agent should first be considered, then a spinal or an epidural block with light general anesthesia should be administered. When general anesthesia must be given, it should be used conservatively, because the pH levels change rapidly during induction and emergence.

It has been found that ether and cyclopropane lower serum potassium levels, so caution must be taken in the choice of agents.\(^1\) Muscle relaxants should be given with caution when a potassium imbalance exists, since it is also believed that the blocking action of nondepolarizing relaxants is enhanced.\(^5\) With this type of emergency patient, who is referred to as a poor-risk patient, solutions containing potassium, given with caution, can restore the acid-base and electrolyte balances.

The emergency patient, who under normal circumstances is healthy, often comes to the operating room in shock caused mainly by fluid loss. General anesthesia is often necessary. If fluid
replacement is adequate, the electrolyte balance often corrects itself. The administration of dextrose, saline, plasma and whole blood are recommended.

The administration of potassium in the early treatment of the emergency patient is often contraindicated. For example, in a patient who has sustained a crushing injury, potassium has left the muscles and there is an abundance in the serum. For a patient in severe shock, with complete or temporary renal shutdown, the administration of potassium could lead to toxicity. In the severely burned patient, potassium has left the cells for tissue serum and, here, renal shutdown is also a problem. Potassium should not be given as an emergency measure until it is certain that renal function exists and that the need for potassium is critical.

POTASSIUM LEVELS

Under normal conditions the total body potassium content averages 45 mEq./kg. of body weight. Only two percent of the total potassium is found in extracellular fluid, the major portion being in intracellular fluid. The total exchangeable body potassium that is available in the average male is 3200 mEq and in the female 2300 mEq.

Plasma levels average 5 milli-equivalents per liter, the average levels being 4.1 to 5.6. The daily intake ranges from 50 to 150 mEq (100 mEq being the average).6

The average requirement of potassium by the body during a 24-hour period is 50 to 150 mEq which represents 1.5 to 5 percent of the total potassium content of the body.6

Abnormal values, those below 4.1 and above 5.6, produce varying effects. Among these are: elevation of T waves at 7 mEq/L; arrhythmia and heart block at 8 to 10 mEq/L; ventricular fibrillation at 12 mEq/L and cardiac arrest following ventricular fibrillation. (Figure 5)

The patient with normal kidneys who is undergoing the stress of disease, without special intake to support the loss of potassium, can lose 80 to 90 mEq in 24 hours.6

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The following preparations are available to correct potassium imbalances. Deficits should be corrected slowly. Not more than 20 mEq per hour should be given.

THAM, also known as tris or tris buffer, is an amino alcohol which has a significant advantage over the sodium salts of bicarbonate and lactate. It diffuses into intracellular compartments. It is less likely to increase the
extracellular fluid value which would cause congestive heart failure.

THAM-E which is tris with electrolytes has an increased potassium content. It is used for the correction of systemic acidosis which accompanies by-pass surgery and the metabolic acidosis associated with cardiac arrest. Patients receiving THAM-E should be monitored because of possible EKG changes.

Ringer's solution contains the salts of sodium, potassium and calcium. It has a higher sodium content than lactated Ringer's solution and has a low potassium content — 4 mEq per 500 cc of solution.

Ringer's Lactate (Hartmann's solution) has magnesium and sodium lactate added to Ringer's solution. This buffered solution is used in the treatment of acidosis and is particularly useful for the poor risk patient. It increases the stroke volume and myocardial contraction. The suggested dosage is 4 mEq/500 cc of solution.

Ionosol electrolyte solutions, produced by Abbott Laboratories, can be used for individual conditions which cause deficiency. The body will retain what is needed and excrete the rest.

Single dose vials of potassium (1 mEq/L, 20 mEq and 40 mEq vials) are available. These are used in 500 cc D5W. They are used for low potassium levels caused by diuretics.

REFERENCES