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Role of Calcium and Magnesium in Anesthesia and Critical Care

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Abstract

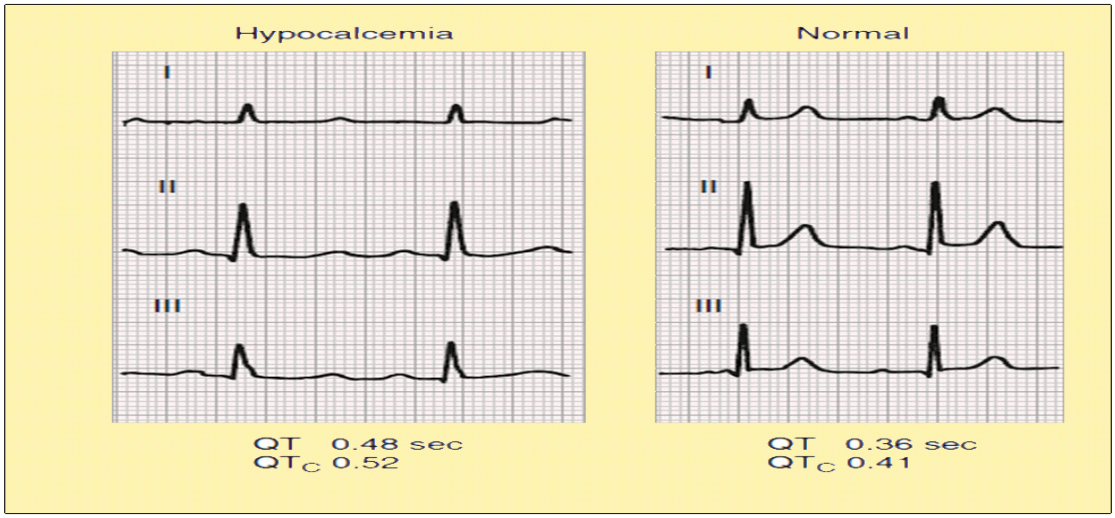
Calcium has an important role in large number of physiological actions that are essential for life. Abnormalities in serum calcium concentration may have profound effects on neurological, gastrointestinal, and renal function. Magnesium is the 4th common cation in body after sodium, potassium and calcium. Intracellular, it is the second most common cation after potassium. Magnesium is widely distributed in plant and animal foods, particularly green vegetables, spices, nuts, soya flour and shellfish. Hypo-magnesemia is reported in up to 20% of patients in medical wards and in as many as 65% of patients in ICUs. In fact, magnesium depletion has been described as "the most underdiagnosed electrolyte abnormality in current medical practice". It is important therefore that the anaesthetist understands calcium and magnesium pathophysiology.

Introduction

Calcium has many essential biological functions which include excitation coupling in myocardial, smooth and skeletal muscle, coagulation of blood, transmission of synapses, hormone secretions and major intracellular messenger for maintaining normal cellular function. Of particular relevance to the anaesthetist are the effects of calcium on the myocardium, vascular smooth muscle and blood coagulation. [1-2]Magnesium is widely distributed in plant and animal foods, particularly green vegetables, spices, nuts, soya flour and shellfish. Many highly-refined flours, fruits and most oils and fats contribute little dietary magnesium. Formula-feed milk has nearly twice the magnesium content of breastmilk. The daily estimated average requirement is 200 mg for females and 250 mg for males. Approximately one-third of dietary magnesium is absorbed, the majority in the small intestine via a passive and saturable transport system, and a small amount (0.8mmol) by the large intestine. Changes in dietary intake or excessive losses are balanced by the kidneys. Most of the magnesium that appears in the glomerular filtrate is reabsorbed in the ascending limb of the loop of Henle with only 1% being excreted in the urine. Parathyroid hormone (PTH) enhances absorption in the gut and reabsorption in the ascending limb of the loop of Henle and distal tubule to maintain the plasma concentration. Aldosterone can increase renal excretion.[9]

Hypocalcemia

Hypocalcaemia is defined as plasma calcium concentration less than 2.1 mmol/L or the ionized calcium level is less than 1.1 mmol/L. Hypocalcaemia is commonly caused by hyperventilation or by excessive citrated red blood cell transfusion; however, the most frequent cause in the critically ill is hypo-albuminaemia.[1,2] Signs and symptoms of hypocalcaemia include mental status changes, tetanus, positive Chvostek sign (contracture of facial muscles produced by tapping the ipsilateral facial nerve) and Trousseau sign (carpopedal spasm with contractions of fingers and an inability to open the hand elicited by inflating an arterial pressure cuff to slightly above the systolic arterial pressure), laryngospasm, hypotension, and cardiac arrhythmias. ECG changes include the prolongation of the QT-interval or AV conduction block.[3,4]



Calcium Salt Solutions

The commonly employed intravenous calcium solutions foe intravenous use include 10% calcium chloride and 10% calcium gluconate, summarized in Table-1. Calcium chloride contains three times more elemental calcium than calcium gluconate, but *calcium gluconate is usually preferred because it has a lower osmolality, and is less irritating when injected*. However both calcium solutions are hyperosmolar and should be given via a large central vein if possible.[5]

Table 1. *Different types of intravenous calcium and their osmolality*

Solution	Elemental Calcium	Osmolarity mOsm/L	Drug Volume
Calcium chloride	27	2000	10 ml
Calcium gluconate	9 mg	680	10 ml

Dosing Regimen

A bolus dose of 100 mg elemental calcium (diluted in 100 mL isotonic saline and given over 5-10 minutes) raise the total serum calcium by 0.5 mg/dL, but level of calcium begins to fall after 30 minutes.Therefore, the bolus dose of calcium should be followed by a continuous infusion at a dose rate of 1 to 2 mg/kg/h (elemental calcium) for at least 6 hours.Individual responses may vary, so calcium dosing should be guided by the level of ionized calcium in blood.[6,7]

Caution

Calcium infusions can promote vasoconstriction and ischemia in any of the vital organs.The risk of calcium-induced ischemia should be particularly high in patients with low cardiac output who are already vaso-constricted. In addition, aggressive calcium replacement can promote intracellular calcium overload, which can produce lethal cell injury, particularly in patients with circulatory shock.Hence, it is wise to avoid correcting ionized hypocalcemia with intravenous calcium unless there is an evidence of serious complication linked to hypocalcemia.[1,3,6,7]

Maintenance Oral calcium Therapy

The daily maintenance dose of calcium is 2-4 g in adults. This can be administered orally using calcium carbonate (e.g., Oscal) or calcium gluconate tablets (500 mg calcium per tablet).

Management of Anesthesia in Hypocalcemia

Symptomatic hypocalcemia must be treated prior to surgery and every effort must be made to minimize any further decrease in serum calcium intraoperatively as may occur with hyperventilation or administration of bicarbonate. Ionized calcium levels may be decreased by massive blood transfusion of blood containing citrate or when the metabolism of citrate is impaired by hypothermia, liver disease or renal failure.Sudden decreases in serum calcium may be seen in the early postoperative period after thyroidectomy or parathyroidectomy and may cause laryngospasm.[8]

Hypercalcemia

Hypercalcemia results from increased calcium reabsorption from the gastrointestinal tract (milk alkali syndrome, vitamin D intoxication, granulomatous

diseases such as sarcoidosis), decreased renal excretion in renal insufficiency and increased bone resorption of calcium (primary or secondary hyperparathyroidism, malignancy, hyperthyroidism and immobilization).[4,7,8]

CLINICAL MANIFESTATIONS

The manifestations of hypercalcemia usually are nonspecific and can be categorized as follows

1. **Gastrointestinal**: nausea, vomiting, constipation, ileus, and pancreatitis
2. **Cardiovascular**: hypovolemia, hypotension, and shortened QT interval
3. **Renal**: polyuria and nephrocalcinosis
4. **Neurologic**: confusion and depressed consciousness, including coma

*These manifestations can become evident when the total serum calcium is > 12mg/d (or the ionizedcalcium is >3.0 mmol/L) and are almost always present when the serum calcium is >14mg/dl (or ionized calcium >3.5mmol/L).*Manifestations are more likely with rapid rises in serum calcium. ECG changes usually involve shortening of QT and QTc interval (Fig 2).

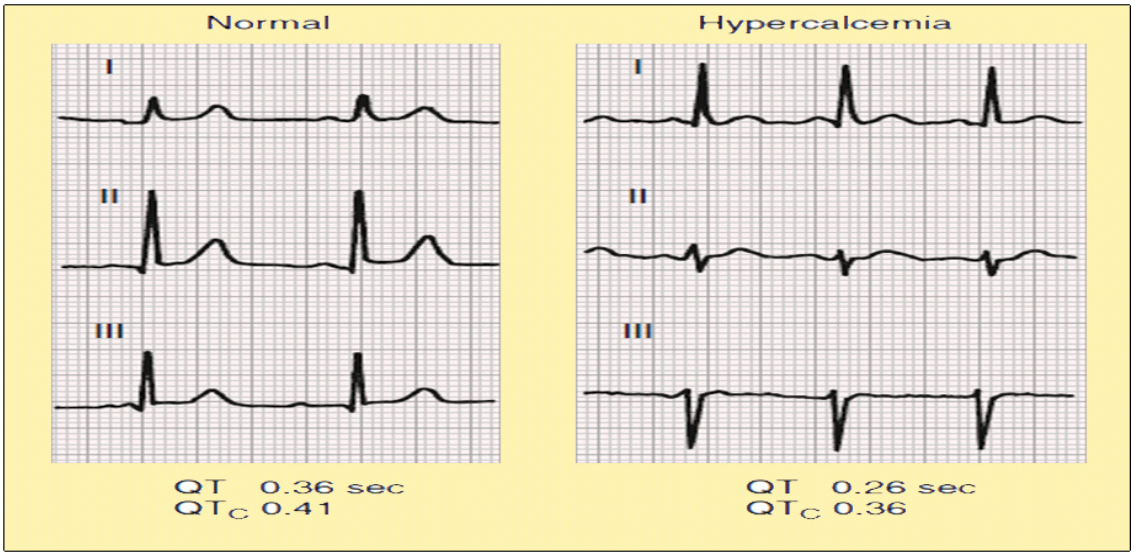


Figure 2. *ECG changes of Hypercalcemia*

Management of Hypercalcemia

Treatment is indicated when hypercalcemia is associated with adverse effects, or when the serum calcium is greater than 14 mg/dL (ionized calcium above 3.5 mmol/L). Most cases of severe, symptomatic hypercalcemia (hypercalcemic crisis) are cancer related.[3,7,8]

Isotonic Saline Infusion

Hypercalcemia usually is accompanied by hypercalciuria, which produces an osmotic diuresis. This eventually leads to hypovolemia, which reduces calcium excretion in the urine and precipitates a rapid rise in the serum calcium. Therefore, volume infusion to correct hypovolemia and promote renal calcium excretion is the first goal of management for hypercalcemia. Isotonic saline (200-500 ml /h) is recommended for the volume infusion because natriuresis promotes renal calcium excretion. The goal is urine output of 100-150 ml/h.[6,8]

Furosemide

Saline infusion will not return the calcium to normal levels. This requires the addition of furosemide (40 to 80 mg IV every 2 hours) to further promote urinary calcium excretion. However, this can be counterproductive because it promotes hypovolemia, so furosemide is recommended only in cases of volume overload.[7]

Calcitonin

Calcitonin is a naturally occurring hormone that inhibits bone resorption.It is available as salmon calcitonin, which is given subcutaneously or intramuscularly in a dose of 4 U/kg every 12 hours. The response is rapid (onset within a few hours), but the effect is mild (the maximum drop in serum calcium is 0.5 mmol/L) and tachyphylaxis is common.As a result, calcitonin has largely been abandoned for the treatment of severe hypercalcemia. [7]

Glucocorticoids

Glucocorticoids decrease serum calcium by increased renal excretion, decreased osteoclast activity in bone and decreased extrarenal production of calcitriol in lymphoma and myeloma.The regimens include oral prednisolone (40 - 100 mg daily) or intravenous hydrocortisone (200-400 mg daily) for 3-5 days. But, glucocorticoid effects may not be evident for 4 days, and they can precipitate tumor lysis syndrome.[8]

Bisphosphonates

They are potent inhibitors of osteoclast activity. Zoledronate (4 or 8 mg IV over 15 min) and Pamidronate (90mg IV over 2 hours) are considered first line agents in the treatment of severe hypercalcemia. Zoledronate is the more effective agent, but higher dose carries a risk of renal injury. Both drugs have a delayed onset of action (2-4 days). The peak effect is 4-7 days and the effect lasts 1-4 weeks. Bisphosphonates should only be given when any clinical dehydration has been treated to avoid calcium bisphosphonate precipitation and nephrotoxicity.[7,8]

Dialysis

Dialysis (hemodialysis or peritoneal dialysis) is effective in removing calcium in patients with renal failure.[7,8]

Management of Anesthesia in Hypercalcemia

1. Management of anesthesia for emergency surgery in a patient with hypercalcemia is aimed at restoring intravascular volume prior to induction and increasing urinary excretion of calcium with loop diuretics (thiazide diuretics should be avoided as they increase renal tubular reabsorption of calcium).
2. Ideally surgery should be postponed until calcium levels have normalized.
3. Central venous pressure or pulmonary artery pressure monitoring may be advisable in patients requiring fluid resuscitation and diuresis as part of their perioperative treatment of hypercalcemia.
4. Dosing of muscle relaxants must be guided by neuromuscular monitoring if muscle weakness, hypotonia or loss of tendon reflexes is present.

Magnesium

The average sized adult contains approximately **24g** of magnesium; a little over half is located in bone, whereas less than 1% is located in plasma. This lack of representation in the plasma limits the value of the plasma Mg as an index of total body magnesium. This is particularly true in patients with magnesium deficiency, in whom plasma magnesium levels can be normal in the face of total body magnesium depletion. Serum is preferred over plasma for magnesium assays because the anticoagulant used for plasma samples can be contaminated with citrate or other anions that bind magnesium.[10]

More Specific Roles of Magnesium Include

Magnesium is an essential element for the utilization of energy in the organic world. The release of energy from ATP requires magnesium, which is an essential cofactor for the ATPase enzymes that hydrolyze ATP. The proper functioning of the Na-K exchange pump (which is Mg dependent ATPase) which generates electrical gradient across cell membranes. As a result, magnesium plays an important role in the activity of electrically excitable tissues.Regulating the movement of calcium into smooth muscle cells, which gives it a pivotal role in the maintenance of cardiac contractile strength and peripheral vascular tone.[11]

Table 3. *Serum Magnesium Range*

Total	1.4 - 2.0 mEq/ L
Ionized	0.8-1.1 mEq/L
Urinary magnesium	5-15 mEq/24 hr

Urinary Magnesium

Under normal circumstances, only small quantities of magnesium are excreted in the urine. When magnesium intake is deficient, the kidneys conserve magnesium, and urinary magnesium excretion falls to negligible levels. The serum magnesium remains in the normal range one week after starting a magnesium deficient diet, while the urinary magnesium excretion drops to negligible levels. [9]

Magnesium Deficiency (Hypomagnesemia)

Hypomagnesemia is defined as serum magnesium concentration ***< 1.4 mEq/L.*** *However, in symptomatic hypomagnesemia, it is usually less than 1mEq/L.*

Magnesium deficiency is common in hospitalized patients. *Hypo-magnesemia is reported in up to 20%*

of patients in medical wards and in as many as 65% of patients in ICUs. In fact, magnesium depletion has been described as **"the most underdiagnosed electrolyte abnormality in current medical practice".**[9,10]

Table 4. *Causes of Hypomagnesemia*

Inadequate intake	Nutritional
Increased renal losses	Diuresis /Postobstructive diuresis Diabetic-ketoacidosis Hyperparathyroidism Hyperaldosteronism Hypophosphatemia Drugs
Reduced gastrointestinal absorption	Malabsorption syndromes Small bowel or biliary fistulas Prolonged nasogastric suctioning Severe diarrhea
Multifactorial	Chronic alcoholism Protein-calorie malnutrition Hyperthyroidism Pancreatitis Burns

Predisposing Conditions

Diuretic Therapy

Diuretics are the leading cause of magnesium deficiency. Urinary magnesium excretion is most pronounced with the loop diuretics (furosemide and ethacrynic acid). Magnesium deficiency has been reported in 50% of patients receiving chronic therapy with furosemide, .

Drug therapy

The drugs that promote magnesium depletion are the aminoglycosides, amphotericin and pentamidine. The aminoglycosides block magnesium reabsorption in the ascending loop of Henle and hypomagnesemia has been reported in 30% of patients receiving aminoglycoside therapy. Prolonged use of proton pump inhibitors (14 days to 13 years) can be associated with severe hypomagnesemia, possibly due to diminished magnesium absorption in the GI tract. A variety of other drugs have been associated with magnesium depletion, including digitalis, epinephrine and the chemotherapeutic agent's cisplatin and cyclosporine. The first two agents shift magnesium into cells, whereas the latter two promote renal magnesium excretion.

Alcohol Related Illness

Hypomagnesemia is reported in 30% of hospital admissions for alcohol abuse, and in 85% of admissions for delirium tremens.The magnesium depletion in these conditions is due to a number of factors, including generalized malnutrition and chronic diarrhea. In addition, there is an association between magnesium deficiency and thiamine deficiency.

Secretory Diarrhea

A high concentration of magnesium (10 to 14mEq/L) is present in secretions from the lower gastrointestinal tract, and thus secretory diarrhea can be accompanied by profound magnesium depletion. Upper tract secretions are not rich in magnesium (1 to 2mEq/L), so vomiting does not pose a risk for magnesium depletion.

Diabetes Mellitus

Magnesium depletion is common in insulin dependent diabetic patients, probably as a result of urinary magnesium losses that accompany glycosuria. Hypomagnesemia is reported in only 7% of admissions for diabetic ketoacidosis, but the incidence increases to 50% over the first 12 hours after admission, probably as a result of insulin-induced movement of magnesium into cells.

Acute Myocardial Infarction

As many as 80% of patients with acute myocardial infarction (MI) can have hypomagnesemia in the first 48 hours after the event. The mechanism is unclear but may be due to an intracellular shift of magnesium caused by endogenous catecholamine excess.

Clinical Manifestations of Magnesium Deficiency

Although no clinical manifestations are specific for magnesium deficiency, the following clinical findings are suggestive of an underlying magnesium deficiency.[9-11]

Associated Electrolyte Abnormalities

Magnesium depletion is often accompanied bydepletion of other electrolytes, such as potassium, phosphate, and calcium. The hypokalemia that accompanies magnesium depletion can be refractory to potassium replacement therapy, and magnesium repletion is often necessary before potassium repletion is possible.Hypokalemia is reported in 40% of patients

with hypomagnesemia. The hypocalcemia that accompanies magnesium depletion is due to impaired parathormone release combined with an impaired end-organ response to parathormone. In addition, magnesium deficiency may act on bone directly to reduce calcium release, independent of parathyroid hormone.

Arrythmias

Magnesium is required for proper function of the membrane pump on cardiac cell membranes, magnesium depletion will depolarize cardiac cells and promote tachyarrhythmias. Digitalis and magnesium deficiency act to inhibit the membrane pump, magnesium deficiency will magnify the digitalis effect and promote digitalis cardiotoxicity. One of the most serious arrhythmias associated with magnesium depletion is torsades de pointes.Prolongation of the P-R and QT intervals may also occur.

Neurological Findings

The neurologic manifestations of magnesium deficiency include altered mentation, generalized seizures, tremors, and hyperreflexia. [12]A neurologic syndrome described recently that can abate with magnesium therapy. The clinical presentation is characterized by ataxia, slurred speech, metabolic acidosis, excessive salivation, diffuse muscle spasms, generalized seizures, and progressive obtundation. The clinical features are often brought out by loud noises or bodily contact, and thus the term **reactive central nervous system magnesium deficiency** has been used to describe this disorder. This syndrome is associated with reduced magnesium levels in cerebrospinal fluid, and it resolves with magnesium infusion.

Diagnosis of Magnesium Deficiency

The serum magnesium level is an insensitive marker of magnesium depletion.

Magnesium Retention Test

In the absence of renal magnesium wasting, the urinary excretion of magnesium in response to a magnesium load may be the most sensitive index of total body magnesium stores.[10]

Protocol

Add 24 mmol of magnesium (6g of MgSO4) to 250 ml of isotonic saline and infuse over 1 hour and collect urine for 24 hours, beginning at the onset of the magnesium infusion

Results

1. Urinary Mg excretion <12 mmol in 24 hours (i.e.less than 50% of the infused Mg) is evidence of Mg depletion.
2. Urinary Mg excretion >19mmol in 24hours (i.e.more than 80% of the infused Mg) is evidence against Mg depletion.

Magnesium Replacement Therapy

The oral preparations can be used for daily maintenance therapy (5 mg/kg in normal subjects). However, because intestinal absorption of oral magnesium is erratic, parenteral magnesium is advised for managing hypomagnesemia. (Table-5)

Table 5. *Types of Magnesium Therapy*

Preparation	Elemental Magnessium
Oral	
Magnesium chloride enteric coated tablets	64 mg (5.3 mEq)
Magnesium oxide tablets (400 mg)	241 mg (19.8 mEq)
Magnesium oxide tablets (140 mg)	85 mg (6.9 meq)
Magnesium gluconate tablet (500 mg)	27 mg (2.3 mEq)
Parenteral Solutions	
Magnesium sulphate (50%)	500 mg/ml (4 mEq/ml)
Magnesium sulphate (12.5%)	120 mg/ml (1 mEq/ml)

Magnesium Sulphate

The standard intravenous preparation is magnesium sulfate (MgSO4). **Each gram of magnesium sulfate has 8 mEq (4 mmol) of elemental magnesium.** A 50% magnesium sulfate solution (500 mg/mL) has an osmolarity of 4000 mOsmL, so it must be diluted to a 10% (100 mg/mL) or 20% (200 mg/mL) solution for

intravenous use. Ringer's solutions should not be used because the calcium in Ringer's solutions will counteract the actions of the infused magnesium.

Replacement Regimen

Mild, Asymptomatic Hypomagnesemia

The following guidelines can be used for patients with mild hypomagnesemia and no apparent complications

1. Assume a total magnesium deficit of 1 to 2mEq/kg.
2. Because 50% of the infused magnesium can be lost in the urine, assume that the total magnesium requirement is twice the magnesium deficit.
3. Replace 1 mEq/kg for the first 24 hours, and 0.5mEq/kg daily for the next 3 to 5 days.

Moderate Hypomagnesemia

The following therapy is intended for patients with a **serum magnesium level less than 1 mEq/L** or when hypomagnesemia is accompanied by other electrolyte abnormalities:

1. Add 6 g MgSO4 (48 mEq Mg) to 250 or 500 mL isotonic saline and infuse over 3 hours.
2. Follow with 5 g MgSO4 (40 mEq Mg) in 250 or 500 mL isotonic saline infused over the next 6 hours.
3. Continue with 5 g MgSO4 every 12 hours (by continuous infusion) for the next 5 days.

Life Threatening Severe Hypomagnesemia

When hypomagnesemia is associated with serious cardiac arrhythmias (e.g., torsades de pointes) or generalized seizures, do the following:

1. Infuse 2 g MgSO4 (16 mEq Mg) intravenously over 2-5 minutes.
2. Follow with 5 g MgSO4 (40 mEq Mg) in 250 or 500 mL isotonic saline infused over the next 6 hours.
3. Continue with 5g MgSO4 every 12 hours (by continuous infusion) for the next 5 days.

Serum magnesium levels will rise after the initial magnesium bolus but will begin to fall after 15 minutes. Therefore, it is important to follow the bolus dose with a continuous magnesium infusion. Serum magnesium levels may normalize after 1 to 2 days, but it will take several days to replenish the total body magnesium stores.

Magnesium Excess (Hypermagnesemia)[11,12]

Magnesium accumulation occurs less frequently than magnesium depletion.

Hypermagnesemia (i.e. serum Mg >2meq/L) has an incidence of nearly 5% in hospitalized patients.

Predisposing Conditions of Magnesium Excess

Renal Insufficiency

Most cases of hypermagnesemia are the result of impaired renal magnesium excretion, which occurs when the creatinine clearance falls below 30 ml/minute.

Hemolysis

The Mg concentration in erythrocytes is approximately three times greater than in serum, so hemolysis can increase the serum Mg. *The serum Mg is expected to rise by 0.1mEq/l for every 250 ml of erythrocytes that lyse completely*, so hypermagnesemia is expected only with massive hemolysis.

Other Conditions

a) Diabetic ketoacidosis,

b) Adrenal insufficiency,

c) Hyperparathyroidism

d) Lithium intoxication

The clinical consequences *of progressive hypermagnesemia are listed below:* (Table-6)

Serum magnesium	Manifestations
4-5 mEq/L	Lethargy, nausea, vomiting and facial flushing.
> 6mEq/L	Loss of deep tendon reflexes and hypotension.
> 10mEq/L	Paralysis, apnea, heart block or cardiac arrest.

Table 6. *Different effects at serum concentration of magnesium*

Magnesium Levels	Effects
5 to 7 mg/dL	Normal therapeutic levels (preeclampsia treatment).
5 to 10 mg/dL	Impaired cardiac conduction (widened QRS, prolong PR), nausea.
20 to 34 mg/dL	Sedation, reduced neuromuscular transmission, hypoventilation, reduced tendon reflexes, and muscle weakness.
24 to 48 mg/dL	Diffuse vasodilation with hypotension,
48 to 72 mg/Dl	Bradycardia Areflexia, coma, respiratory paralysis.

Magnesium has been described as **nature's physiologic Calcium Blocker**, and most of the serious consequences of hypermagnesemia are due to calcium antagonism in the cardiovascular system. ECG signs include prolongation of P-R interval and widening of QRS complex.

Management of Hypermagnesemia

- Hemodialysis is the treatment of choice for severe hypermagnesemia.
- Intravenous calcium gluconate (1 g IV over 2 to 3 minutes) can be used to antagonize the cardiovascular effects of hypermagnesemia temporarily, until dialysis is started.
- If fluids are permissible and some renal function is preserved, aggressive volume infusion combined with furosemide may be effective in reducing the serum magnesium levels in less advanced cases of hypermagnesemia.

Magnesium and its Various Clinical Roles

Anesthesia Considerations of Hypermagnesemia

1. Requires close monitoring of the ECG, blood pressure, and neuromuscular function.
2. Potentiation of the vasodilating and negative inotropic properties of anaesthetics should be expected.
3. A urinary catheter is required when diuretic and saline infusions are used to enhance magnesium excretion.
4. Serial measurements of Ca^{2+} and Mg^{2+} may be useful.
5. Potentiates NM blockade, both depolarising and non depolarisingagents.Dosages of NMBAs should be reduced by 25-50%.

Magnesium and Neuromuscular Blockade[13]

a) After a dose of magnesium sulphate 40 mg per kg, the ED_{50} of vecuronium is reduced by 25%, onset time nearly halved and recovery time nearly doubled.

b) The reduction in onset time of non depolarizing block has been used to produce intubation condition more rapidly.

c) As recovery time is prolonged after magnesium, it has little place in rapid sequence intubation as an alternative to succinylcholine. There are some reports of antagonism of the block produced by succinylcholine.

Recently, the importance of magnesium in anesthetic practice has been highlighted.It has been suggested that magnesium has the potential to treat and prevent pain by acting as an antagonist of N-methyl-d-aspartate (NMDA) receptors. It has been reported that magnesium administration led to a significant reduction in fentanyl consumption in the peri- and postoperative periods. Magnesium sulfate (MgS04) is widely utilized in the treatment of pre eclamptic hyperreflexia. In eclampsia magnesium sulphate decreases chances of recurrent seizures. Such therapy has important anaesthetic implications because Increase in plasma magnesium potentiates the activity of both depolarizing and nondepolarizing neuromuscular blocking agents. Magnesium sulphate may have beneficial effects on both maternal and uteroplacental hemodynamics in pre-eclampsia and regional block appears safe in the presence of magnesium sulphate.

Magnesium in Asthma[13,14]

In asthma and allergic rhinitis, intracellular calcium concentrations increase in response to IgE stimulation leading to histamine release; this can be antagonized by magnesium.It also has action on smooth muscle

contraction and acetylcholine release from cholinergic nerve terminals. In asthma, bronchospasm (requiring intracellular calcium) is antagonized by magnesium. Magnesium also influences function of respiratory muscles. It also modulates inflammatory process and decrease the release of free radicals.

Magnesium in Acute Myocardial Infarction[13,14,15]

Magnesium provides cellular protection during ischaemia. It drives calcium into thesarcoplasmic reticulum and reduces mitochondrial calcium overload. This leads to the limitation of infarct size. Inhibits cellular potassium loss which helps in prevention of arrhythmia. It decreases reperfusion injury by inhibiting calcium overload, also protects from free radical damage.

Magnesium in Arrhythmia

Magnesium deficit exacerbates potassium mediated arrhythmias by a complex interaction which mediated arrhythmias by modifying action potential. It is recommended that both potassium and magnesium are administered for rapid control of arrhythmias associated with potassium depletion. Magnesium acts by slow inward calcium current block, which decreases sinus node rate, prolongs AV conduction time and increases AV node refractoriness.

Magnesium in Critical Care[13-15]

Current estimates of hypomagnesaemia are as high as 65% in adult ICU and 30% in NICU patients from various studies. The reasons for such high rates are

- Decreased absorption caused by impaired gastrointestinal activity,
- Malnutrition,
- Renal wasting of various drugs(digoxin, loopdiuretics, gentamicin),
- Diabetes mellitus,
- Hypokalemia and Hypocalcemia.

Magnesium in Tetanus[13-15]

Magnesium helps in reducing spasms and autonomic instability of tetanus with an IV dose of 5 g over 20 min followed by 2g/hr. If necessary dose may be increased by 0.5g/hr till relief of spasm or loss of patellar reflexes occur. If continuous infusion is not possible a dose of 2.5g/hr may be administered every 2hrs, adjusting frequency with symptomatic relief.

Others

- Magnesium reduces postoperative shivering.
- It obtunds the pressor response to laryngoscopy and intubation by decreasing catecholamine release.
- It is also used in treatment of respiratory failure and neonatal pulmonary hypertension.
- It has also been used as an agent to decrease catecholamine release during pheochromocytoma surgery.
- **Other areas** in which magnesium may have a role include *dementia, restless leg syndrome and chronic fatigue syndrome,* where deficiency of magnesium may cause excess activity at NMDA receptors, loss of cell fluidity and decreased calcium release and effect.

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