

# Electrolyte Disturbances in the Hospital Setting

Electrolyte imbalances are common in hospitalized patients and can lead to significant morbidity if not addressed. This document provides an overview of sodium, potassium, calcium, magnesium, and phosphate disturbances, focusing on causes, evaluation, complications, and treatments for students.

## Sodium Disorders

### Hyponatremia (Na <135 mEq/L)

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- **Causes:**

- **Hypovolemic:** Dehydration (diuretics, vomiting, diarrhea), third-spacing (burns, pancreatitis).
- **Euvolemic:** Syndrome of inappropriate antidiuretic hormone (SIADH; e.g., small cell lung cancer, SSRIs), hypothyroidism, adrenal insufficiency.
- **Hypervolemic:** Cirrhosis, heart failure, nephrotic syndrome (edematous states).
- **Pseudohyponatremia:** Hyperglycemia (Na decreases 1.6 mEq/L per 100 mg/dL glucose >100), hypertriglyceridemia, hyperproteinemia.

- **Evaluation:**

- **Serum Sodium:** Confirm true hyponatremia (Na <135 mEq/L).
- **Serum Osmolality:** Hypotonic (<280 mOsm/kg) vs. isotonic (pseudohyponatremia).
- **Urine Sodium:** <20 mEq/L (hypovolemic), >40 mEq/L (SIADH, renal salt wasting).
- **Urine Osmolality:** >100 mOsm/kg (SIADH, dehydration), <100 mOsm/kg (psychogenic polydipsia).
- **Volume Status:** Assess for edema, JVD, skin turgor, orthostatics.
- **Other Labs:** Glucose, TSH, cortisol (rule out hypothyroidism, adrenal insufficiency).

- **Complications:**

- **Acute (<48 hours):** Cerebral edema → Seizures, coma, death.
- **Chronic:** Fatigue, confusion, gait instability, falls.
- **Overcorrection:** Osmotic demyelination syndrome (ODS; Na correction >8-12 mEq/L/day) → Quadriplegia, dysarthria, locked-in syndrome.

- **Treatment:**
  - **Acute Symptomatic (Seizures, Coma):**
  - **Hypertonic saline (3% NaCl):** 100-150 mL IV bolus over 10-15 min, repeat x1 if needed.
    - **Goal:** Increase Na by 4-6 mEq/L in first 6 hours, then slow correction.
  - **Chronic Asymptomatic:**
    - **Hypovolemic:** Isotonic saline (0.9% NaCl) 1-2 L IV, titrate to volume status.
    - **Euvolemic (SIADH):** Fluid restriction (<800 mL/day), salt tablets (3-6 g/day), demeclocycline 600-1200 mg/day (if refractory).
    - **Hypervolemic:** Loop diuretics (furosemide 40 mg IV), fluid restriction, treat underlying cause (e.g., heart failure).
- **Monitoring:** Na q4-6h, limit correction to 6-8 mEq/L/day to prevent ODS.
- **Key Tip:** If overcorrection occurs (>8 mEq/L/day), re-lower Na with D5W (3-6 mL/kg/h) or desmopressin (2-4 mcg IV q8h).

## **Hypernatremia (Na >145 mEq/L)**

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- **Causes:**
  - **Water Loss:** Dehydration (fever, burns, diarrhea), diabetes insipidus (central or nephrogenic), osmotic diuresis (hyperglycemia).
  - **Sodium Gain:** Hypertonic saline administration, sodium bicarbonate overdose.
- **Evaluation:**
  - **Serum Sodium:** Confirm Na >145 mEq/L.
  - **Serum Osmolality:** Hypertonic (>300 mOsm/kg).
  - **Urine Osmolality:** <300 mOsm/kg (diabetes insipidus), >600 mOsm/kg (dehydration).
  - **Water Deficit:** Calculate:  $[(Na - 140) / 140] \times \text{total body water (TBW)}$ ; 50% body weight in women, 60% in men).
  - **Other Labs:** Glucose, urine specific gravity, ADH level (if DI suspected).
- **Complications:**
  - **Acute:** Brain shrinkage → Intracranial hemorrhage, seizures, coma.
  - **Chronic:** Lethargy, irritability, muscle cramps.
  - **Overcorrection:** Cerebral edema (Na drop >10-12 mEq/L/day).
- **Treatment:**
  - **Acute Symptomatic:**
    - **D5W or 0.45% NaCl:** 1-2 mL/kg/h IV, adjust based on water deficit.
    - **Goal:** Decrease Na by 0.5 mEq/L/h, max 10-12 mEq/L/day.

- **Chronic Asymptomatic:**
  - **Oral free water:** 1-2 L/day, or D5W IV if unable to drink.
- **Treat underlying cause:** Desmopressin 1-2 mcg IV q12h (central DI), thiazides (nephrogenic DI).
- **Monitoring:** Na q4-6h, avoid rapid correction to prevent cerebral edema.
- **Key Tip:** Correct slowly; rapid correction risks cerebral edema.

## Potassium Disorders

### Hypokalemia (K <3.5 mEq/L)

- **Causes:**
  - **Decreased Intake:** Malnutrition, anorexia.
  - **Increased Loss:** GI (vomiting, diarrhea), renal (diuretics, RTA, hypomagnesemia).
  - **Intracellular Shift:** Alkalosis, insulin, beta-agonists (albuterol).
- **Evaluation:**
  - **Serum Potassium:** K <3.5 mEq/L.
  - **EKG:** Flattened T waves, U waves, prolonged QT, ventricular arrhythmias.
  - **Other Labs:** Mg (correct hypomagnesemia first), arterial pH (alkalosis), urine K (renal loss if >30 mEq/L).
- **Complications:**
  - **Arrhythmias:** Atrial/ventricular ectopy, torsades de pointes (if QT prolonged).
  - Muscle weakness, rhabdomyolysis, paralysis.
  - Ileus, constipation.
- **Treatment:**
  - **Mild (K 3.0-3.5 mEq/L, Asymptomatic); Oral KCl:** 40-60 mEq/day in divided doses.
  - **Severe (K <3.0 mEq/L or Symptomatic): IV KCl:** 10-20 mEq/h via central line (max 40 mEq/h in ICU), dilute in 100 mL saline.
  - **Correct Mg first:** MgSO<sub>4</sub> 2 g IV over 1 hour.
- **Monitoring:** K q4h, EKG for arrhythmias, monitor for rebound hyperkalemia.
- **Key Tip:** Always correct Mg first; hypomagnesemia causes refractory hypokalemia.

## Hyperkalemia (K >5.0 mEq/L)

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- **Causes:**
  - **Pseudohyperkalemia:** Hemolysis, prolonged tourniquet, thrombocytosis.
  - **Increased Intake:** K supplements, salt substitutes.
  - **Decreased Excretion:** AKI, CKD, hypoaldosteronism (e.g., ACEi, spironolactone), adrenal insufficiency.
  - **Extracellular Shift:** Acidosis, rhabdomyolysis, tumor lysis syndrome.
- **Evaluation:**
  - **Serum Potassium:** K >5.0 mEq/L.
  - **EKG:** Peaked T waves, widened QRS, sine wave, asystole.
  - **Other Labs:** BUN/Cr (renal function), pH (acidosis), CK (rhabdomyolysis), aldosterone.
- **Complications:**
  - **Arrhythmias:** Bradycardia, ventricular fibrillation, asystole.
  - Muscle weakness, paralysis.
- **Treatment:**
  - Emergency (EKG Changes or K >6.5 mEq/L):
    - **Stabilize myocardium:** Calcium gluconate 1-2 g IV over 2-5 min.
    - **Shift K intracellularly:** Insulin 10 units IV + D50 25 g IV, albuterol 10-20 mg nebulized.
    - **Remove K:** Furosemide 40 mg IV, sodium polystyrene sulfonate (SPS) 15-30 g PO, dialysis (if refractory).
  - Non-Emergency (K 5.0-6.5 mEq/L, No EKG Changes):
    - **Stop K-sparing drugs:** ACEi, ARBs, spironolactone.
    - Furosemide 40 mg PO/IV, SPS 15 g PO.
- **Monitoring:** K q2-4h, repeat EKG, monitor glucose (insulin).
- **Key Tip:** Calcium gluconate first for EKG changes; dialysis for refractory cases.

## Calcium Disorders

### Hypocalcemia (Ca <8.5 mg/dL, Corrected)

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- **Causes:**
  - **Decreased Intake/Absorption:** Vitamin D deficiency, malabsorption.
  - **Increased Loss:** Hypoparathyroidism (post-thyroidectomy), pseudohypoparathyroidism.
  - **Sequestration:** Pancreatitis, rhabdomyolysis, citrate (blood transfusions).

- **Evaluation:**
  - **Serum Calcium:** Correct for albumin:  $\text{Corrected Ca} = \text{measured Ca} + 0.8 \times (4 - \text{albumin})$ .
  - **Ionized Calcium:** <4.6 mg/dL (more accurate).
  - **Other Labs:** PTH, 25-OH vitamin D, Mg, Cr (CKD).
- **EKG:** Prolonged QT, arrhythmias.
- **Complications:**
  - Tetany, seizures, laryngospasm.
  - Arrhythmias, heart failure.
- **Treatment:**
  - **Symptomatic (Tetany, Seizures):**
    - **IV calcium gluconate:** 1-2 g IV over 10-20 min, then infusion 0.5-1 mg/kg/h.
  - **Asymptomatic:**
    - **Oral calcium:** Calcium carbonate 1-2 g/day.
    - **Vitamin D:** Calcitriol 0.25-1 mcg/day (if PTH low).
- **Monitoring:** Ca q6-8h, ionized Ca, EKG.
- **Key Tip:** Correct Mg first; hypomagnesemia causes refractory hypocalcemia.

## Hypercalcemia (Ca >10.5 mg/dL, Corrected)

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- **Causes:**
  - **Primary Hyperparathyroidism:** Parathyroid adenoma (most common outpatient cause).
  - **Malignancy:** PTHrP (squamous cell cancer), osteolytic metastases (breast cancer), 1,25-OH vitamin D (lymphoma).
  - **Other:** Hypervitaminosis D, sarcoidosis, thiazides.
- **Evaluation:**
  - **Serum Calcium:** Correct for albumin.
  - **PTH:** High (hyperparathyroidism), low (malignancy).
  - **Other Labs:** 25-OH vitamin D, 1,25-OH vitamin D, Cr, SPEP/UPEP (multiple myeloma).
  - **EKG:** Shortened QT, arrhythmias.
- **Complications:**
  - Nephrolithiasis, nephrocalcinosis, AKI.
  - Confusion, lethargy, coma ("stones, bones, groans, psychic moans").
- **Treatment:**
  - **Severe (Ca >14 mg/dL or Symptomatic):**
    - **IV fluids:** 0.9% NaCl 2-4 L IV over 24h (promotes calciuresis).
    - **Calcitonin:** 4 units/kg IM/SC q12h (rapid onset, tachyphylaxis after 48h).

- **Bisphosphonates:** Zoledronic acid 4 mg IV over 15 min (long-term control, onset 24-48h).
- **Mild (Ca 10.5-12 mg/dL, Asymptomatic):**
  - Stop thiazides, vitamin D.
  - **Oral hydration:** 2-3 L/day.
- **Monitoring:** Ca q6-12h, Cr, EKG.
- **Key Tip:** IV fluids first, then calcitonin/bisphosphonates; dialysis for refractory cases.

## Magnesium Disorders

### Hypomagnesemia (Mg <1.8 mg/dL)

- **Causes:**
  - **Decreased Intake/Absorption:** Malnutrition, alcoholism, malabsorption.
  - **Increased Loss:** GI (diarrhea), renal (diuretics, cisplatin, alcohol).
- **Evaluation:**
  - **Serum Magnesium:** Mg <1.8 mg/dL.
  - **Other Labs:** K, Ca (hypomagnesemia causes hypokalemia/hypocalcemia).
  - **EKG:** Prolonged QT/PR, torsades de pointes.
- **Complications:**
  - Tetany, seizures, arrhythmias (torsades).
  - Refractory hypokalemia/hypocalcemia.
- **Treatment:**
  - **Symptomatic (Seizures, Arrhythmias):**
    - **IV MgSO<sub>4</sub>:** 2 g IV over 10-20 min, then 1-2 g/h infusion.
  - **Asymptomatic:**
    - **Oral Mg:** Magnesium oxide 400-800 mg/day.
- **Monitoring:** Mg q6-12h, EKG, monitor for hypermagnesemia (hyporeflexia).
- **Key Tip:** Correct Mg before K or Ca; hypomagnesemia causes refractory imbalances.

### Hypermagnesemia (Mg >2.5 mg/dL)

- **Causes:**
  - **Increased Intake:** Mg-containing antacids/laxatives, IV Mg overdose.
  - **Decreased Excretion:** CKD, AKI.
- **Evaluation:**
  - **Serum Magnesium:** Mg >2.5 mg/dL.

- **Other Labs:** Cr, EKG (widened QRS, bradycardia).
- **Complications:**
  - Hyporeflexia, respiratory depression, cardiac arrest.
- **Treatment:**
  - **Severe (Mg >5 mg/dL or Symptomatic):**
    - Stop Mg intake.
    - **IV calcium gluconate:** 1-2 g IV (antagonizes Mg effects).
    - **IV fluids + furosemide:** 0.9% NaCl 1-2 L + furosemide 40 mg IV.
    - **Dialysis:** If renal failure or refractory.
  - **Mild (Mg 2.5-5 mg/dL, Asymptomatic):**
    - Stop Mg intake, monitor.
- **Monitoring:** Mg q6-12h, EKG, reflexes.
- **Key Tip:** Calcium gluconate for severe symptoms; dialysis for renal failure.

## Phosphate Disorders

### Hypophosphatemia (PO<sub>4</sub> <2.5 mg/dL)

- **Causes:**
  - **Decreased Intake/Absorption:** Malnutrition, alcoholism, vitamin D deficiency.
  - **Increased Excretion:** Hyperparathyroidism, diuretics, refeeding syndrome.
  - **Intracellular Shift:** Refeeding syndrome, respiratory alkalosis, insulin.
- **Evaluation:**
  - **Serum Phosphate:** PO<sub>4</sub> <2.5 mg/dL.
  - **Other Labs:** Ca, PTH, 25-OH vitamin D, urine PO<sub>4</sub>.
- **Complications:**
  - Muscle weakness, rhabdomyolysis, respiratory failure.
  - Hemolysis, impaired oxygen delivery (low 2,3-DPG).
- **Treatment:**
  - **Severe (PO<sub>4</sub> <1.5 mg/dL or Symptomatic):**
    - **IV sodium phosphate:** 0.2-0.5 mmol/kg IV over 6h.
  - **Mild (PO<sub>4</sub> 1.5-2.5 mg/dL, Asymptomatic):**
    - **Oral phosphate:** Sodium phosphate 500-1000 mg TID.
- **Monitoring:** PO<sub>4</sub> q6-12h, Ca (risk of hypocalcemia with IV repletion).
- **Key Tip:** Avoid rapid IV repletion; risk of hypocalcemia, metastatic calcification.

## Hyperphosphatemia (PO<sub>4</sub> >4.5 mg/dL)

- **Causes:**
  - **Decreased Excretion:** AKI, CKD, hypoparathyroidism.
  - **Increased Intake/Release:** Phosphate enemas, rhabdomyolysis, tumor lysis syndrome.
- **Evaluation:**
  - **Serum Phosphate:** PO<sub>4</sub> >4.5 mg/dL.
  - **Other Labs:** Ca, Cr, PTH, CK (rhabdomyolysis).
- **Complications:**
  - Hypocalcemia (Ca-PO<sub>4</sub> precipitation), metastatic calcification.
  - AKI (phosphate nephropathy).
- **Treatment:**
  - **Severe (PO<sub>4</sub> >6 mg/dL or Symptomatic):**
    - **IV fluids:** 0.9% NaCl 1-2 L to enhance excretion.
    - **Dialysis:** If renal failure or refractory.
  - **Mild (PO<sub>4</sub> 4.5-6 mg/dL, Asymptomatic):**
    - **Phosphate binders:** Sevelamer 800-1600 mg TID with meals.
- **Monitoring:** PO<sub>4</sub> q6-12h, Ca, Cr.
- **Key Tip:** Treat underlying cause (e.g., CKD); avoid binders if acute (e.g., tumor lysis).

## Electrolyte Disturbance Overview Table

Electrolyte	Abnormality	Common Causes	Evaluation Serum/urine	Complications
Sodium	Hyponatremia (<135)	SIADH, diuretics, cirrhosis, dehydration	osmolality, urine Na	Seizures, ODS, cerebral edema
Sodium	Hypernatremia (>145)	Dehydration, diabetes insipidus, Na load	osmolality, urine osmolality	Brain hemorrhage, seizures
Potassium	Hypokalemia (<3.5)	Diuretics, vomiting, alkalosis, insulin	EKG, Mg, urine K	Arrhythmias, weakness, ileus
Potassium	Hyperkalemia (>5.0)	AKI, acidosis, ACEi, rhabdomyolysis	EKG, Cr, pH, aldosterone	Arrhythmias, paralysis
Calcium	Hypocalcemia (<8.5)	Hypoparathyroidism, vitamin D deficiency	Ionized Ca, PTH, Mg, vitamin D	Tetany, seizures, arrhythmias
Calcium	Hypercalcemia (>10.5)	Hyperparathyroidism, malignancy, sarcoidosis	PTH, 25-OH vitamin D, SPEP	Nephrolithiasis, AKI, confusion



Electrolyte	Abnormality	Common Causes	Evaluation Serum/urine	Complications
Magnesium	Hypomagnesemia (<1.8)	Alcoholism, diuretics, diarrhea	Mg, K, Ca, EKG	Seizures, torsades, tetany
Magnesium	Hypermagnesemia (>2.5)	CKD, Mg overdose (antacids, IV)	Mg, Cr, EKG	Hyporeflexia, respiratory depression
Phosphate	Hypophosphatemia (<2.5)	Refeeding syndrome, alcoholism, diuretics	PO <sub>4</sub> , Ca, PTH, urine PO <sub>4</sub>	Weakness, hemolysis, respiratory failure
Phosphate	Hyperphosphatemia (>4.5)	CKD, tumor lysis, phosphate enemas	PO <sub>4</sub> , Ca, Cr, PTH	Hypocalcemia, AKI, calcification

## Treatment Guidelines Table

Electrolyte	Abnormality	Treatment (Symptomatic)	Treatment (Asymptomatic)	Monitoring
Sodium	Hyponatremia	Please refer to separate hyponatremia document	Please refer to separate hyponatremia document	Na q4-6h, limit 6-8 mEq/L/day
Sodium	Hypernatremia	D5W 1-2 mL/kg/h IV	Oral free water, D5W IV	Na q4-6h, max 10-12 mEq/L/day
Potassium	Hypokalemia	IV KCl 10-20 mEq/h (central line)	Oral KCl 40-60 mEq/day	K q4h, EKG
Potassium	Hyperkalemia	Calcium gluconate, insulin/D50, dialysis	Furosemide, SPS	K q2-4h, EKG
Calcium	Hypocalcemia	IV calcium gluconate 1-2 g over 10-20 min	Oral calcium carbonate 1-2 g/day	Ca q6-8h, EKG
Calcium	Hypercalcemia	0.9% NaCl 2-4 L, calcitonin, zoledronic acid	Oral hydration, stop thiazides	Ca q6-12h, Cr, EKG
Magnesium	Hypomagnesemia	IV MgSO <sub>4</sub> 2 g over 10-20 min	Oral Mg oxide 400-800 mg/day	Mg q6-12h, EKG
Magnesium	Hypermagnesemia	Calcium gluconate 1-2 g IV, dialysis	Stop Mg intake, IV fluids	Mg q6-12h, reflexes
Phosphate	Hypophosphatemia	IV sodium phosphate 0.2-0.5 mmol/kg	Oral phosphate 500-1000 mg TID	PO <sub>4</sub> q6-12h, Ca
Phosphate	Hyperphosphatemia	IV fluids, dialysis	Phosphate binders (sevelamer)	PO <sub>4</sub> q6-12h, Ca, Cr

## Complications Table

Electrolyte	Abnormality	Neurologic	Cardiac	Other
Sodium	Hyponatremia	Seizures, coma, ODS	None	Gait instability, falls
Sodium	Hypernatremia	Seizures, coma	None	Intracranial hemorrhage
Potassium	Hypokalemia	Weakness, paralysis	Arrhythmias, torsades	Rhabdomyolysis, ileus
Potassium	Hyperkalemia	Weakness, paralysis	Ventricular fibrillation	None
Calcium	Hypocalcemia	Tetany, seizures	Arrhythmias, heart failure	Laryngospasm
Calcium	Hypercalcemia	Confusion, coma	Short QT, arrhythmias	Nephrolithiasis, AKI
Magnesium	Hypomagnesemia	Seizures, tetany	Torsades, arrhythmias	Refractory hypokalemia
Magnesium	Hypermagnesemia	Hyporeflexia	Bradycardia, cardiac arrest	Respiratory depression
Phosphate	Hypophosphatemia	Weakness	None	Hemolysis, respiratory failure
Phosphate	Hyperphosphatemia	None	None	Hypocalcemia, AKI, calcification

### Examples

#### 1. Case 1: Hyponatremia in Heart Failure

**o Presentation:** 65 y/o F with heart failure, Na 128 mEq/L, edema, JVD, serum osmolality 270 mOsm/kg, urine Na 50 mEq/L.

**o Interpretation:** Hypervolemic hyponatremia (heart failure).

**o Management:** Furosemide 40 mg IV, fluid restriction (<1 L/day), monitor Na q6h.

#### 2. Case 2: Hyperkalemia in AKI

**o Presentation:** 50 y/o M with AKI, K 6.8 mEq/L, Cr 3.5 mg/dL, EKG with peaked T waves.

**o Interpretation:** Hyperkalemia due to AKI.

o **Management:** Calcium gluconate 1 g IV, insulin 10 units IV + D50 25 g IV, dialysis, monitor K q2h.

### 3. Case 3: Hypocalcemia Post-Thyroidectomy

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o **Presentation:** 40 y/o F post-thyroidectomy, Ca 7.8 mg/dL, tetany, prolonged QT on EKG.

o **Interpretation:** Hypocalcemia (hypoparathyroidism).

o **Management:** IV calcium gluconate 2 g over 20 min, calcitriol 0.5 mcg/day, monitor Ca q6h.

### 4. Case 4: Hypomagnesemia in Alcoholism

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o **Presentation:** 55 y/o M with alcoholism, Mg 1.2 mg/dL, K 3.0 mEq/L, seizures.

o **Interpretation:** Hypomagnesemia (alcoholism), causing hypokalemia.

o **Management:** IV MgSO<sub>4</sub> 2 g over 20 min, then 1 g/h, oral KCl 40 mEq, monitor Mg/K q6h.

### 5. Case 5: Hyperphosphatemia in Tumor Lysis

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o **Presentation:** 60 y/o M with leukemia post-chemotherapy, PO<sub>4</sub> 6.5 mg/dL, Ca 7.5 mg/dL, Cr 2.0 mg/dL.

o **Interpretation:** Hyperphosphatemia (tumor lysis syndrome).

o **Management:** IV fluids (0.9% NaCl 2 L), dialysis, monitor PO<sub>4</sub>/Ca q6h.

## Key Pearls

- **Hyponatremia:** Correct slowly (6-8 mEq/L/day) to avoid ODS; use 3% NaCl for seizures.
- **Hyperkalemia:** Calcium gluconate first for EKG changes; dialysis for refractory cases.
- **Hypocalcemia:** Correct Mg first; IV calcium for tetany/seizures.
- **Hypomagnesemia:** Correct before K/Ca; IV MgSO<sub>4</sub> for seizures/arrhythmias.
- **Hyperphosphatemia:** IV fluids first; binders for CKD, dialysis for acute severe cases.

## References

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- **AAFP:** "Management of Hyponatremia and Hyperkalemia" (2024).
- **NEJM:** "Hypercalcemia of Malignancy" (2023).
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