Yoğun Bakım Hastalarında Elektrolit Bozuklukları

Dr Elif Arı Bakır
Bahçeşehir Üniversitesi Tıp Fakültesi
2018

Giriş

- Elektrolitler tüm yaşamsal faaliyetlerde

  - Metabolik ve homeostatik fonksiyonlar
  - Hücre membranı yapısı ve fonksiyonları
  - Sinir hücresi iletimi
  - Hormon fonksiyonları
  - Kas kontraksiyon mekanizması
  - Kardiyovasküler fizyoloji
  - Kemik metabolizması
  - Sıvı dengesi
  - Asit-baz dengesi

Yoğun Bakım Ünitesi Hastaları ve Elektrolitler

- Sodyum ve su metabolizması
- Potasyum metabolizması
- Kalsiyum-fosfor metabolizması
- Magnezyum metabolizması
- Asit-baz dengesi

Semptomların şiddeti elektrolit bozukluğunun şiddetine ve gelişme hızına bağlı

Nefroloji ve Yoğun Bakım Ünitesi

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Role of the nephrologist in the intensive care unit

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Abstract

In 1998, Drs. Claudio Ronco and Ronaldo Bellomo published an article in *Nephrology, Dialysis and Transplantation* (NDT) entitled "Critical Care Nephrology: the time has come" [1]; in that

- A.B.D'de 2. ve 3. basamak hastanelerde istenen Nefroloji konsultasyonlarının % 20-38 i Yoğun Bakım (YBÜ) hastalarından
- Tüm YBÜ hastalarının % 6-30 undan Nefroloji görüşü isteniyor
- En sık tanı Akut Böbrek Hasarı (% 50-75)
- Elektrolit bozukluğu tanısı % 7-9

Nefroloji ve Yoğun Bakım Ünitesi

Editorial – Role of the Nephrologist in Multidisciplinary Management of AKI

Blood Purification

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Critical Care Nephrology: A Multidisciplinary Approach

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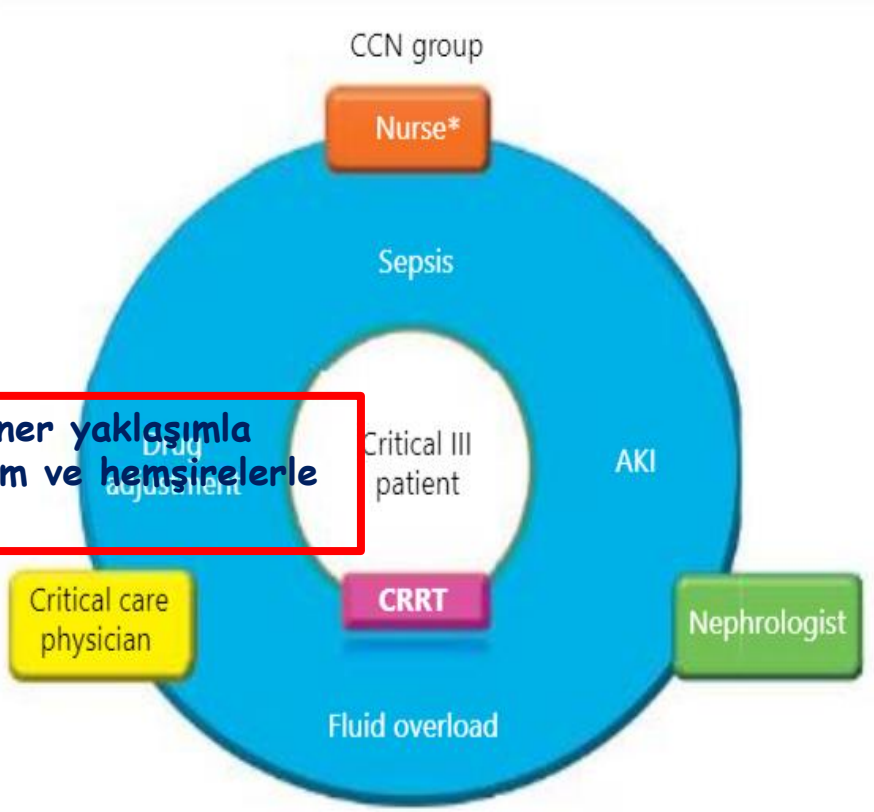
YBÜ Hastaları multi-disipliner yaklaşımla entegre çalışan uzman hekim ve hemşirelerle tedavi edilebilir



Key Words
Critical care nephrology · Acute kidney injury · Acute kidney disease · Precision medicine

Abstract
Acute kidney injury (AKI) is a serious medical condition affecting millions of people. Patients in intensive care unit (ICU) who develop AKI have increased morbidity and mortality, prolonged length of stay in ICU and hospital and increased costs, especially when they require renal replace-

Introduction

Acute kidney injury (AKI) is a serious medical condition affecting more than 10 million people around the world [1] The incidence in the intensive care unit (ICU) population is between 20 and 30% depending on the used definition, and more than 10% of all patients admitted to the ICU require renal replacement therapy (RRT) for AKI [2]. The spectrum of AKI has recently expanded to the phase of recovery that may require a follow up for a period as long as 3 months. In this time window, the syn-

Yoğun Bakım Hastalarında Elektrolit Bozuklukları- Genel Mekanizmalar

- Elektrolit emilim ve vücut sıvılarında dağılım değişikliği
- Elektrolit içerikli sıvıların yetersiz veya fazla verilmesi
- Hormonal dengenin bozulması
- Gastrointestinal veya renal kayıplar
- Sıvı dengesinde veya dağılımında değişiklikler

CLINICAL REVIEW

Treatment of electrolyte disorders in adult patients in the intensive care unit

MICHAEL D. KRAFT, IMAD F. BTAICHE, GORDON S. SACKS, AND KENNETH A. KUDSK

Electrolytes are involved in many metabolic and homeostatic functions, including enzymatic and biochemical reactions, the maintenance of cell membrane structure and function, neurotransmission, nerve signal conduction, hormone function, muscle contraction, cardiovascular function, bone composition, and fluid and acid–base regulation. In addition to serum electrolyte concentrations, signs and symptoms of specific electrolyte disorders should be monitored in patients with electrolyte abnormalities. The severity of symptoms related to electrolyte disorders generally correlates with the severity of the disorder and the rate at which the disorder developed. Multiple mechanisms may be involved in electrolyte abnormalities in adult patients in the intensive care unit (ICU), including altered absorption and distribution; excessive or inadequate administration; alterations in hormonal, neuro-

Purpose. The treatment of electrolyte disorders in adult patients in the intensive care unit (ICU), including guidelines for correcting specific electrolyte disorders, is reviewed.

Summary. Electrolytes are involved in many metabolic and homeostatic functions. Electrolyte disorders are common in adult patients in the ICU and have been associated with increased morbidity and mortality, as has the improper treatment of electrolyte disorders. A limited number of prospective, randomized, controlled studies have been conducted evaluating the optimal treatment of electrolyte disorders. Recommendations for treatment of electrolyte disorders in adult patients in the ICU are provided based on these studies, as well as case reports, expert opinion, and clinical experience. The etiologies of and treatments for hyponatremia hypotonic and hypernatremia (hypovolemic, isovolemic, and hypervolemic), hypokalemia and hyperkalemia, hypophosphatemia and hyperphosphatemia, hypocalcemia and hypercalcemia, and hypomagnesemia and hypermagnesemia are discussed, and equations for determining the proper dosages for adult patients in the ICU are provided. Treatment is often empirical, based on published literature, expert recommendations, and the patient's response to the initial treatment. Actual electrolyte correction requires individual adjustment based on the patient's clinical condition and response to therapy. Clinicians should be knowledgeable about electrolyte homeostasis and the underlying pathophysiology of electrolyte disorders in order to provide the optimal therapy to patients.

Conclusion. Treatment of electrolyte disorders is often empirical, based on published literature, expert opinion and recommendations, and patient's response to the initial treatment. Clinicians should be knowledgeable about electrolyte homeostasis and the underlying pathophysiology of electrolyte disorders to provide optimal therapy for patients.

Index terms: Calculations; Critical illness; Dosage; Electrolytes; Equations; Methodology; Mortality; Protocols; Water-electrolyte imbalance

Am J Health-Syst Pharm. 2005; 62:1663-82

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Olgu-1

- 41 yaş, E
- Bilinç bulanıklığı
- 2 gün önce bilincinin iyi olduğu biliniyor
- Özgeçmişinde şizofreni tanısıyla anti-psikotik kullanmakta
- Ağır sigara içicisi

- FM:
  TA: 140/70 mmHg, Nb: 88/dk, A: 36,1, SS: 15
  Övolemik

- Emerg Med J, 2001; 18(6):520

Olgu-1

- LAB:
  Serum sodyum: 113 mmol/L,
  Serum potasyum: 3,4 mmol/L
  Serum klor: 76 (100-110) mmol/L
  Serum HCO3: 25 (22-33) mmol/L

  Parasetamol ve salisilatlar için serum toksikoloji taraması (-)

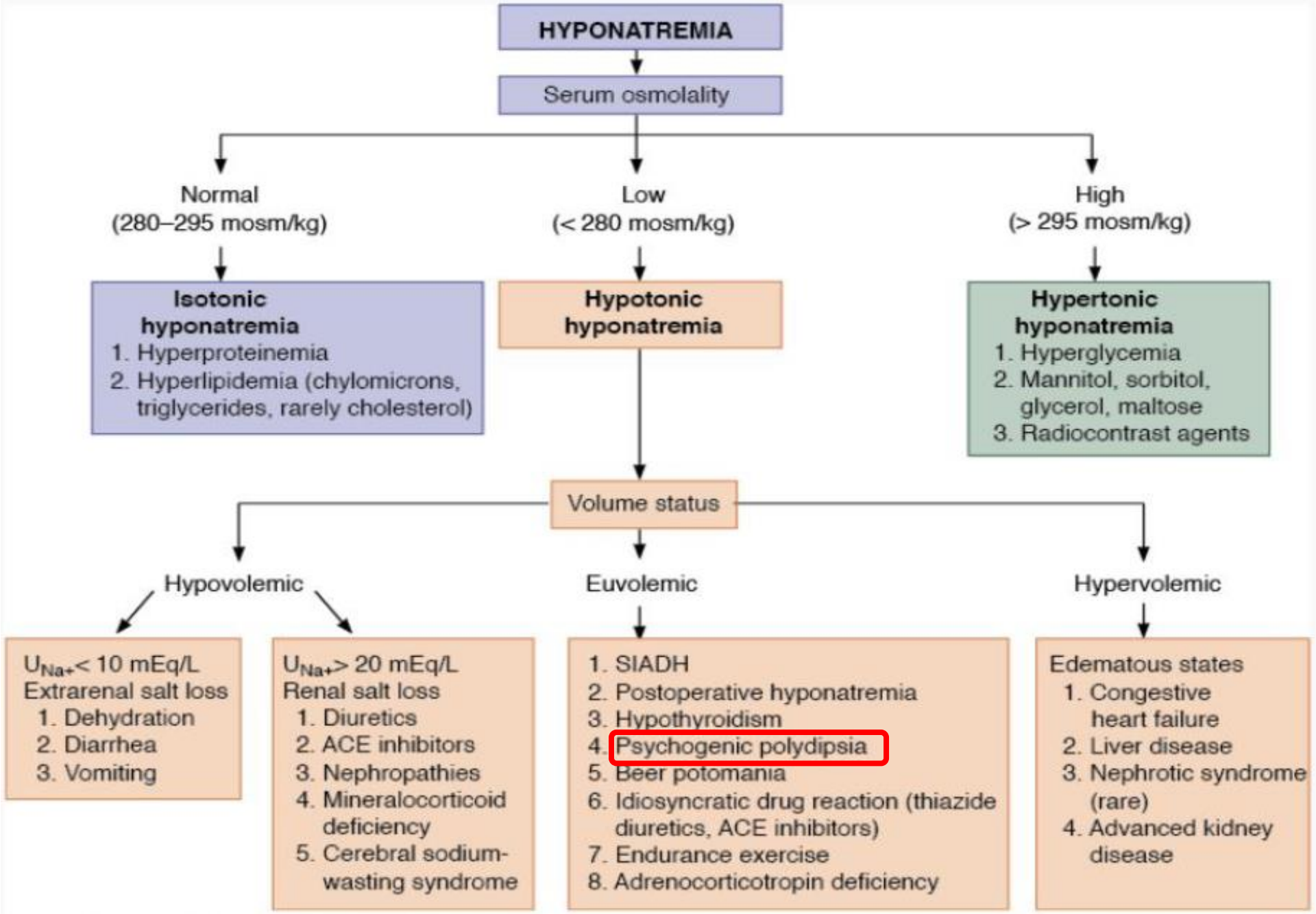
  İdrar sodyum: 29 mmol/L
  İdrar potasyum: 6,7 mmol/L

Olgu-1

- Sıvı durumunu değerlendirmek
  - Hasta övolemik

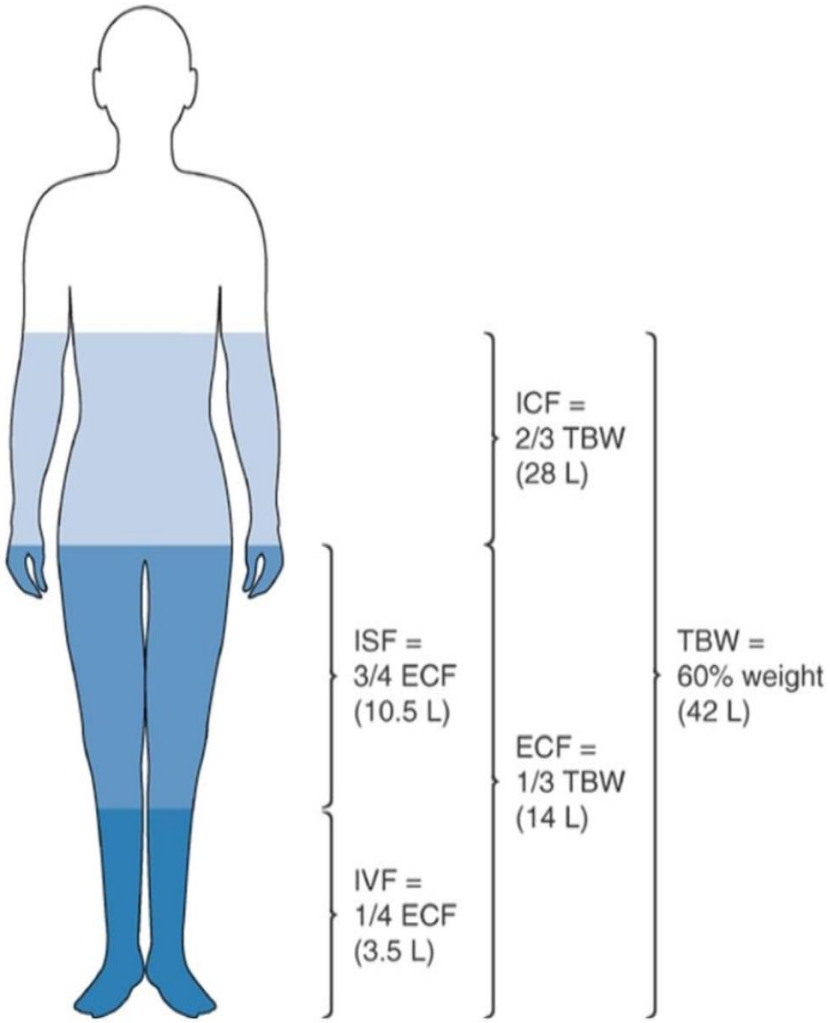
- Osmolaliteyi değerlendirmek
  - = (2xNa) + (glukoz/18) + (BUN/2.8)
    Serum osmolalitesi 266
    Hasta hipotonik

- İdrar sodyum atılımını ve fraksiyone sodyum atılımını değerlendirmek
  - idrar sodyumu yüksekse idrar konsantrasyon bozukluğu



Source: McPhee SJ, Papadakis MA: *Current Medical Diagnosis and Treatment 2010*, 49th Edition: http://www.accessmedicine.com

Sodyum ve Su Metabolizması



The NEW ENGLAND JOURNAL of MEDICINE

REVIEW ARTICLE

DISORDERS OF FLUIDS AND ELECTROLYTES

Julie R. Ingelfinger, M.D., *Editor*

Disorders of Plasma Sodium — Causes, Consequences, and Correction

Richard H. Sterns, M.D.

HUMAN CELLS DWELL IN SALT WATER. THEIR WELL-BEING DEPENDS ON the ability of the body to regulate the salinity of extracellular fluids. By controlling water intake and excretion, the osmoregulatory system normally prevents the plasma sodium concentration from straying outside its normal range (135 to 142 mmol per liter). Failure of the system to regulate within this range exposes cells to hypotonic or hypertonic stress. This review considers the causes and consequences of an abnormal plasma sodium concentration and offers a framework for correcting it.

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N Engl J Med 2015;372:55-65.
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PLASMA SODIUM CONCENTRATION AND EXTRACELLULAR TONICITY

The plasma sodium concentration affects cell volume. The term "tonicity" describes the effect of plasma on cells — hypotonicity makes cells swell and hypertonicity makes them shrink. Hypernatremia always indicates hypertonicity. Hyponatremia usually indicates hypotonicity, but there are exceptions (e.g., hyperglycemic hyponatremia and pseudohyponatremia) that are not covered in this review.

PLASMA SODIUM CONCENTRATION AND THE ELECTROLYTE AND WATER CONTENT OF THE BODY

Hiponatremi

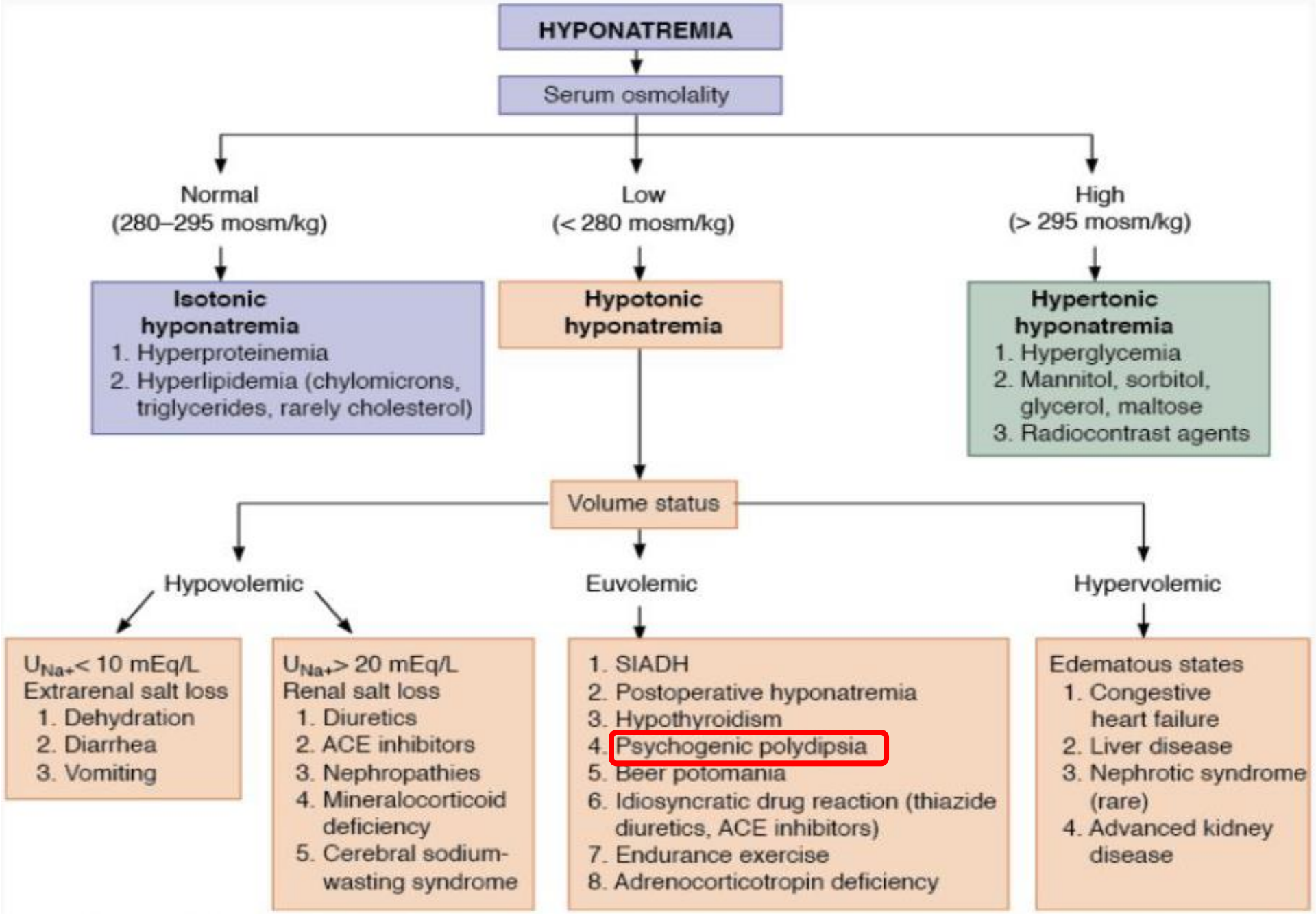
Drugs associated with hyponatremia*	
Vasopressin Analogs	Drugs That Potentiate Renal Action of Vasopressin
Desmopressin (DDAVP)	Chlorpropamide
Oxytocin	Cyclophosphamide
	Nonsteroidal anti-inflammatory drugs
	Acetaminophen
Drugs That Enhance Vasopressin Release	Drugs That Cause Hyponatremia by Unknown Mechanisms
Chlorpropamide	*Haloperidol*
Clofibrate	Fluphenazine
Carbamazepine-oxycarbazepine	Amitriptyline
Vincristine	Thioridazine
Nicotine	Fluoxetine
Narcotics	*Methamphetamine (MDMA or Ecstasy)*
Antipsychotics/antidepressants	Sertraline
Ifosfamide	

Hiponatremi

Causes of the syndrome of inappropriate vasopressin release (SIADH)

Carcinomas	Pulmonary disorders	Nervous system disorders	Other
Bronchogenic carcinoma	*Viral pneumonia*	*Encephalitis (viral or bacterial)*	*AIDS–HIV*
Carcinoma of the duodenum	*Bacterial pneumonia*	*Meningitis (viral, bacterial, tuberculous, and fungal)*	*Idiopathic (elderly)*
Carcinoma of the pancreas	*Pulmonary abscess*	*Head trauma*	Prolonged exercise
Thymoma	*Tuberculosis*	*Brain abscess*	
Carcinoma of the stomach	Aspergillosis	*Brain tumors*	
Lymphoma	Positive pressure breathing	Guillain–Barré syndrome	
Ewing's sarcoma	Asthma	Acute intermittent porphyria	
Carcinoma of the bladder	Pneumothorax	Subarachnoid hemorrhage or subdural hematoma	
Prostatic carcinoma	Mesothelioma	Cerebellar and cerebral atrophy	
Oropharyngeal tumor	Cystic fibrosis	Cavernous sinus thrombosis	
Carcinoma of the ureter		Neonatal hypoxia	
		Hydrocephalus	
		Shy–Drager syndrome	
		Rocky Mountain spotted fever	
		Delirium tremens	
		Cerebrovascular accident (cerebral thrombosis or hemorrhage)	
		Acute psychosis	
		Peripheral neuropathy	
		Multiple sclerosis	

With permission from Berl and Schrier[20]
Italics: the common causes.



Source: McPhee SJ, Papadakis MA: *Current Medical Diagnosis and Treatment 2010*, 49th Edition: http://www.accessmedicine.com

Hiponatremi

Na açığını nasıl hesaplamalı ?

Na açığı = Dağılım hacmi x Litredeki Na açığı

E:%60
K:%50

Düzeltme hızı hiçbir zaman
- 0.5 mEq/L/saat
- 12 mEq/L/gün'ü

GEÇMEMELİDİR

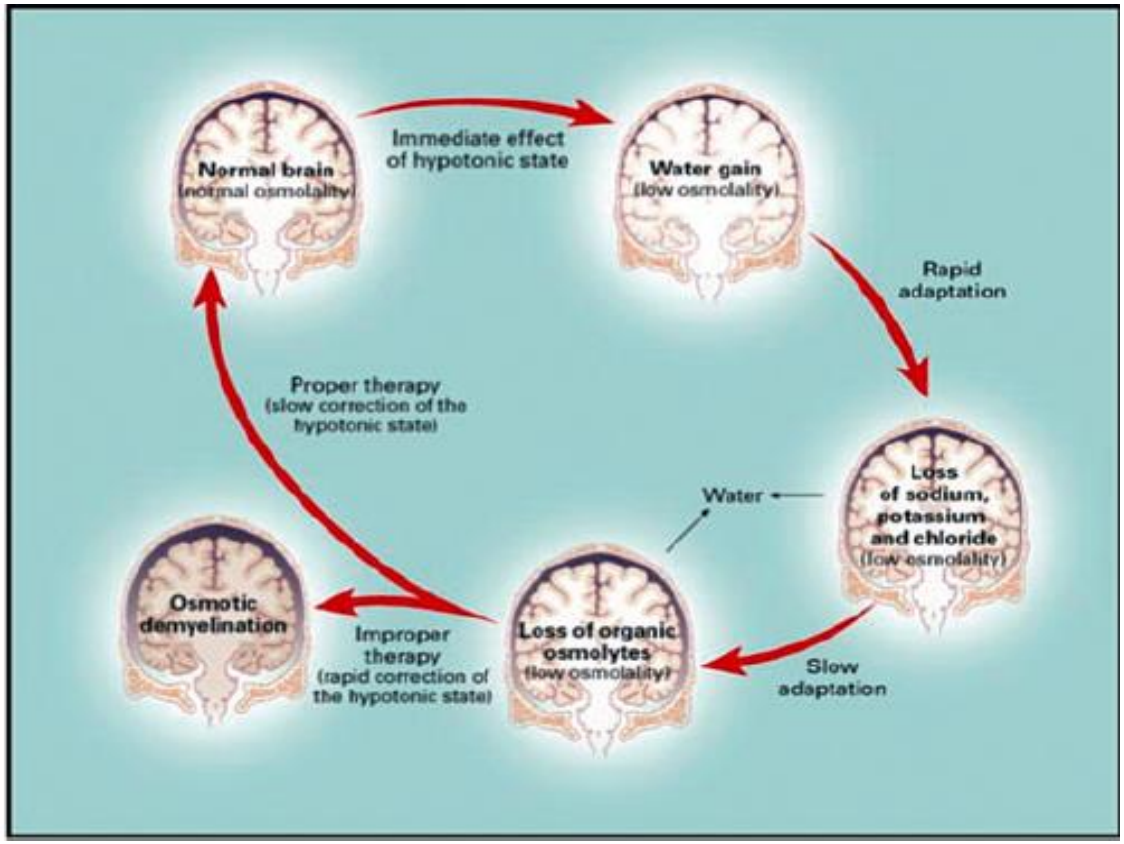
4-6 saatte bir sNa'unu ölç ve yeniden hesapla

Serumların Na içeriği

- 1000 cc % 0.9 izotonik NaCl :
  - 154 mEq
- % 3 NaCl (hipertonik):
  - 513 mEq
- % 20 NaCl (Serum Sale) (hipertonik) 10 cc amp
  - 33 mEq

Hiponatremi Tedavisi

Kronik Hiponatremi → **Hızlı düzeltmekten KAÇININ**



<u>Major komplikasyon:</u>
Sentral pontine miyelinolizis

Ozmotik Demiyelinizasyon
Nasıl Önleyebiliriz?

- 24 saatte 10-12 mEq/L aşılmamalı

- Akut su zehirlenmesi düşündürtecek bir hikayesi yok ve geçmişini bilinmiyorsa kronik kabul edilmeli

- Sık ölçüm yapılmalı
  - İdrar çıkışını takip ederek
  - Serum sodyum monitorizasyonu yapılarak
    (başlangıçta 4-6 saatte bir)

Hiponatremi

- Akut semptomatik hiponatremi tedavi edilmezse kalıcı nörolojik hasar riski yüksektir

- Kronik hiponatremi hızla tedavi edilirse ozmotik demiyelinizasyon riski yüksektir

Primum non nocere

Tedavi

- Hipo ve normovolemik hiponatremide sodyum düzeyinin 48 saatten kısa sürede 120-125 mEq/L'nin altına düştüğü semptomatik olgularda acil tedavi gereklidir

- Acil durumlarda semptomlar gerileyene kadar saatlik sodyum miktarını 1 mEq/L kadar arttıracak şekilde %3 (hipertonik) NaCl uygulanır

Tedavi

- Daha hafif olgularda ise düzeltme hızı 0.5 mEq/L'dir
- Hafif asemptomatik olgularda replasman solüsyonu olarak izotonik NaCl de uygulanabilir
- Kronik asemptomatik hiponatremide ise altta yatan neden tedavi edilir

Olgu-1
İzlem ve Tedavi

- Yüzeyel solunum nedeniyle endotrakeal entübasyon ve MV uygulaması
- Hiponatremi düzeltilmesi
- %3 hipertonik salin infüzyonu
- Saatte 1 mEq/L sodyum artışı
- Bilinç düzeyinde düzelme ile 72 saat sonra ekstübasyon

- Tanı: Psikojenik polidipsi

- Şizofreni hastalarının %17 sinde
- Psikojenik polidipsi ile anti-psikotik kullanımı arasında ilişki

Olgu-1
İzlem ve Tedavi

- Tanı: Psikojenik polidipsi

Altta yatan organik bir sebep olmadan, fizyolojik bir uyaran yokken büyük hacimli sıvı tüketilmesi

- Şizofreni hastalarının %17 sinde
- Ciddi hiponatremi (serum Na<120 mmol/l) vakaların % 20 si
- Psikojenik polidipsi ile anti-psikotik kullanımı arasında ilişki

- Mayo Clin Proc 1995; 70:473-476
- Arch Intern Med 1995; 155:953-957

Olgu-2

- 79 yaş, E
- Bilinç bulanıklığı 10 gündür
- 3 gündür bilinci iyice bozulmuş, oral alımı minimal
- Son 24 saattir idrar çıkışı azalmış
- Özgeçmişinde demans öyküsü var, yalnız yaşamını sürdürüyor

- FM:
  TA: 140/70 mmHg, Nb: 88/dk, A: 36,1, SS: 22
  Hafif dehidrate görünümde

- Mayo Clin Proc 1998; 76:273-276

Olgu-2

- LAB:

  Serum sodyum: 170 mmol/L,
  Serum potasyum: 4,9 mmol/L
  Serum klor: 104 (100-110) mmol/L
  Serum HCO3: 24 (22-33) mmol/L

Hipernatremi

Major causes of hypernatremia

Unreplaced water loss (which requires an impairment in either thirst or access to water)
Insensible and sweat losses
Gastrointestinal losses
Central or nephrogenic diabetes insipidus
Osmotic diuresis
Glucose in uncontrolled diabetes mellitus
Urea in high-protein tube feedings
Mannitol
Hypothalamic lesions impairing thirst or osmoreceptor function
Primary hypodipsia
Reset osmostat in mineralocorticoid excess
Water loss into cells
Severe exercise or seizures
Sodium overload
Intake or administration of hypertonic sodium solutions

Klinik Bulgular

- Ateş
- Bulantı, kusma
- Aşırı susama hissi
- Letarji
- Reflekslerde artış
- Huzursuzluk
- Konvülsiyonlar
- Koma

Özellikle yaşlı ve entübe hastalar susama hissinin körelmesi veya suya erişimin olmaması nedeniyle risk altındadır

Hipernatremi Tedavisi

SU AÇIĞININ HESAPLANMASI

- Toplam vücut sıvısı (TVS) = Vücut ağırlığı x 0.6 (E) veya 0.5 (K)

$$\text{Su açığı} = \frac{(\text{Serum } [Na^+] - 140)}{140} \times \text{TVS}$$

- Su açığı 48-72 saatte düzeltilmelidir
- Serum [Na+]'daki düşüş saatte 0.5 mEq/L'yi geçmemelidir
- Hissedilmeyen sıvı kayıpları (30-50 ml/saat) eklenmelidir
- Hastada şuur bozukluğu yoksa, su oral yoldan verilir
- Parenteral tedavi:
- Hipotonik sıvılar (%0.45 NaCl veya %5 dektroz) verilir.
- Devam eden kayıplar varsa (diyare vs.) buna eklenmelidir.

Olgu-3

- 51 yaş, E
- İştahsızlık, baş dönmesi, bulantı-kusma, kilo kaybı
- Birkaç aydır bel-sırt ağrısı ve ciltte koyulaşma
- Özgeçmişinde 1 yıl önce geçirilmiş menisküs diz ameliyatı dışında özellik yok

- FM:

  TA: 90/50 mmHg, şiddetli ortostatik hipotansiyon

  Nb: 90/dk, A: 37,4, SS: 24

  Solgun görünümlü, sağ inguinal LAP (+) ler

Olgu-3

- LAB:
  Serum sodyum: 121 mmol/L,
  Serum potasyum: 7,4 mmol/L
  Serum klor: 116 (100-110) mmol/L,
  Serum HCO3: 19 (22-33) mmol/L

  Serum kreatinin: 2.2 mg/dl
  Eritrosit sedimentasyon hızı: 87 mm/saat
  CRP: 35 mg/L
  Serum kortizol: 5 mg/dl (düşük)

- Case report Med 2012; 205:574845

Olgu-3

- Üst batın MR: Bilateral asimetrik genişlemiş böbreküstü bezleri
- İnguinal yüzeyel USG: kalınlaşmış korteks ile genişlemiş, hipoekoik, sağ inguinal lenf nodları
- İnguinal lenf nodu biyopsisi: Kazeifiye, granülomatöz lenfadenit
- Tanı: Miliyer Tbc – bilateral böbreküstü bezi tutuluma sekonder hipoaldosteronizm

Major causes of hyperkalemia

Increased potassium release from cells
Pseudohyperkalemia
Metabolic acidosis
Insulin deficiency, hyperglycemia, and hyperosmolality
Increased tissue catabolism
Beta blockers
Exercise
Hyperkalemic periodic paralysis
Other
Overdose of digitalis or related digitalis glycosides
Red cell transfusion
Succinylcholine
Arginine hydrochloride
Activators of ATP-dependent potassium channels (eg, calcineurin inhibitors, diazoxide, minoxidil, and some volatile anesthetics)
Reduced urinary potassium excretion
Reduced aldosterone secretion
Reduced response to aldosterone
Reduced distal sodium and water delivery
Effective arterial blood volume depletion
Acute and chronic kidney disease
Other
Selective impairment in potassium secretion
Gordon's syndrome
Ureterojejunostomy

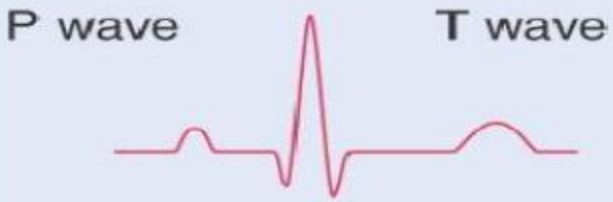
Major causes of hypoaldosteronism

Reduced aldosterone production
Hyporeninemic hypoaldosteronism
Renal disease, most often diabetic nephropathy
Nonsteroidal anti-inflammatory drugs
Calcineurin inhibitors
Volume expansion, as in acute glomerulonephritis
Angiotensin inhibitors, such as ACE inhibitors, angiotensin II receptor blockers, and direct renin inhibitors
Chronic heparin Rx (impairs aldosterone synthesis)
Primary adrenal insufficiency
Severe illness
Inherited disorders
Congenital hypoaldosteronism (21 hydroxylase deficiency and isolated hypoaldosteronism)
Pseudohypoaldosteronism type 2 (Gordon's syndrome)
Aldosterone resistance
Inhibition of the epithelial sodium channel
Potassium-sparing diuretics, such as spironolactone, eplerenone, amiloride, and triamterene
Antibiotics, trimethoprim, and pentamidine
Pseudohypoaldosteronism type 1
Voltage defects
Markedly reduced distal Na delivery
Acquired or congenital defects in Na reabsorption by the distal tubule principal cells (obstructive uropathy), SLE, and sickle cell disease

Medications associated with hyperkalemia

Class	Mechanism	Example*
Potassium-containing medicines	Increased potassium intake	KCl, PCN G, PolyCitra, PolyCitra K
β-adrenergic receptor blockers	Inhibit renin release	Propranolol, metoprolol, atenolol
ACE inhibitor	Inhibit conversion of Angiotensin I to Angiotensin II	Captopril, lisinopril
Angiotensin receptor blocker (ATRA)	Inhibit activation of AT1 receptor by Angiotensin II	Losartan, valsartan, irbesartan
Heparin	Inhibit aldosterone synthase, rate limiting enzyme for aldosterone synthesis	Heparin sodium
Aldosterone receptor antagonist	Block aldosterone receptor activation	Spironolactone
Potassium-sparing diuretic	Block collecting duct apical sodium channel, decreasing gradient for potassium secretion	Amiloride, triamterene, trimethoprim, pentamidine
NSAID and COX-2 inhibitors	Inhibit prostaglandin stimulation of collecting duct potassium secretion, inhibits renin release	Ibuprofen, rofecoxib
Digitalis glycosides	Inhibit Na^+-K^+-ATPase necessary for collecting duct potassium secretion	Digoxin
Calcineurin inhibitors	Inhibit Na^+-K^+-ATPase necessary for collecting duct potassium secretion	Cyclosporine, tacrolimus

ECG changes in hyperkalemia

QRS complex	Approximate serum potassium (mmol/l)	ECG change
	~4	Normal
	6–7	Peaked T waves
	7–8	Flattened P wave, prolonged PR interval, depressed ST segment, peaked T wave
	8–9	atrial standstill, prolonged QRS duration, further peaking T waves
	>9	Sine-wave pattern

Acil Tedavi Endikasyonları

- Nörolojik bulgular
- EKG değişiklikleri
- Potasyum düzeyi >6.5 mEq/L

Acil Tedavide Hedefler

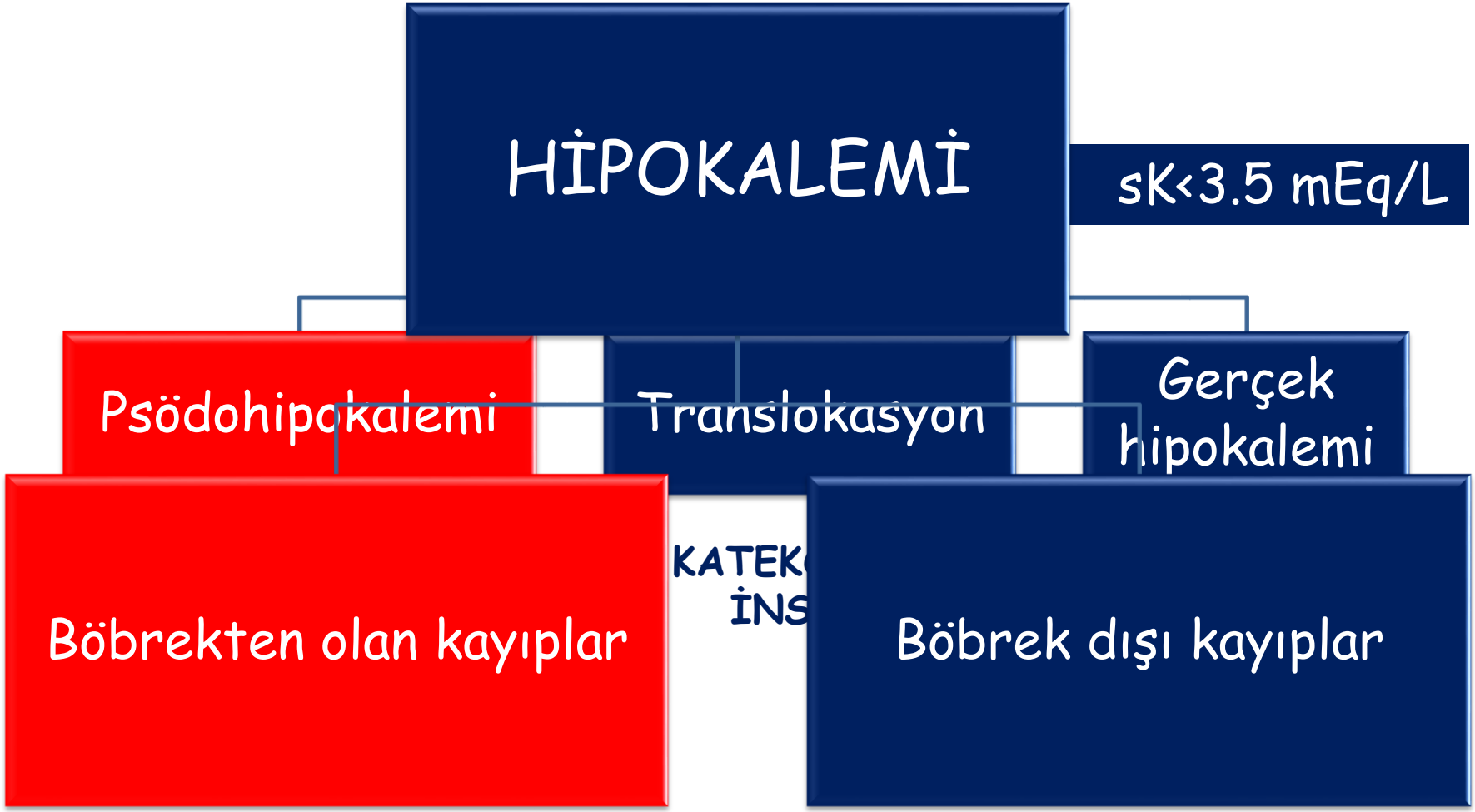
- Kalbi hiperkaleminin istenmeyen etkilerinden korumak
  - Kalsiyum karbonat infüzyonu

- Ektrasellüler potasyumun hücre içine geçişini sağlamak
  - Glukoz + insülin
  - β_2-agonist tedavi

Bahsedilen tedavi yöntemleri acil durumlarda etkin olmakla birlikte geçici çözümlerdir.

Acil Tedavide Hedefler

- Fazla potasyumu vücuttan uzaklaştırmak
  - Polistiren sülfonat
  - Potasyumdan fakir diyet
  - Hiperkalemiye yol açan ilaçlar kesilir
  - Diüretikler
  - Diyaliz


HİPOKALEMİ
sK<3.5 mEq/L
Psödohipokalemi
Translokasyon
Gerçek hipokalemi
Böbrekten olan kayıplar
KATEK
İNS
Böbrek dışı kayıplar

Hipokalemi

Renal Kayıplar

- Diüretikler, amfoterisin B, sisplatin gibi bazı ilaçlar
- Genetik tubulopatiler
- Renal tubuler asidoz
- Aldosteron sentezinde artış

Ekstrarenal Kayıplar

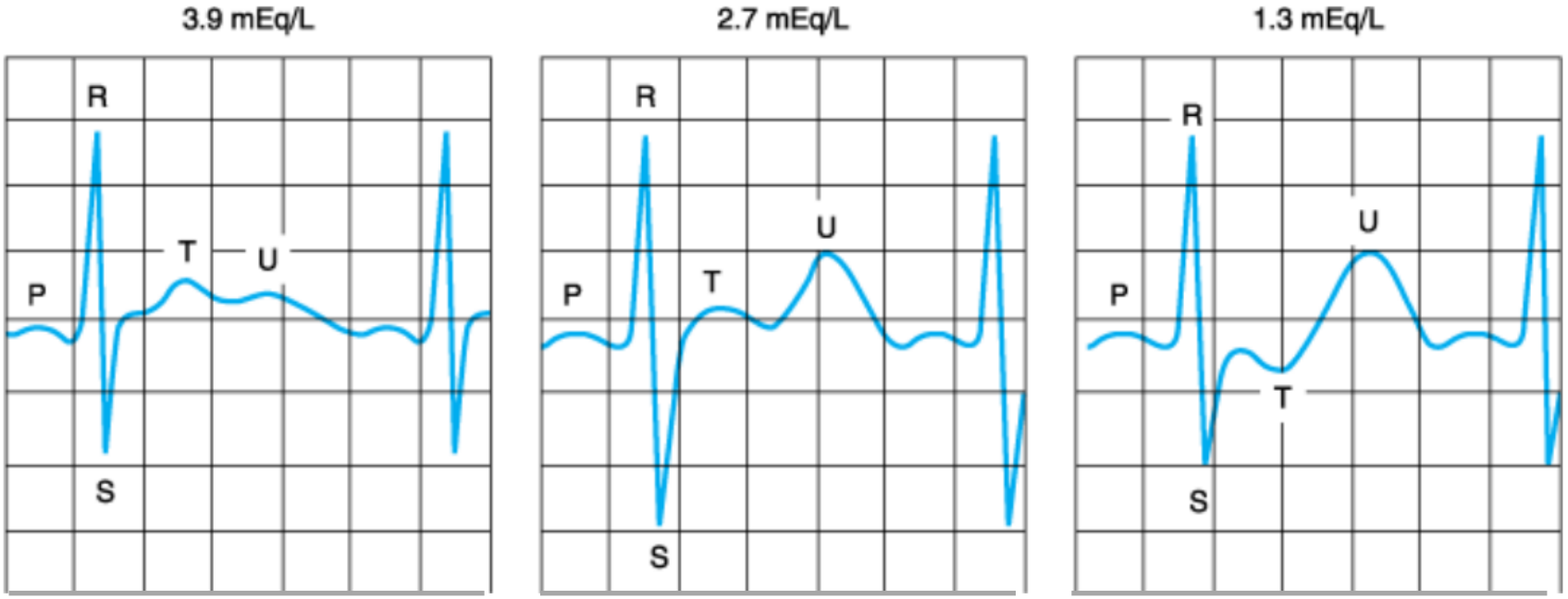
- Kusma
- İshal
- Laksatif kullanımı

Hipomagnezeminin de potasyum kaybını arttırdığı akılda tutulmalıdır

Semptomlar

- Semptomlar genellikle <3 mEq/L'de başlar.
- Hafif: Halsizlik, kas güçsüzlüğü
- Ağır: Hipoventilasyon, paralizi, rabdomyoliz, paralitik ileus ve kardiyak aritmi gibi ciddi kardiyak ve nörolojik komplikasyonlar

Hipokalemide EKG



T dalgasında progresif düzleşme
Giderek belirginleşen U dalgası
P dalgasının amplitüdünde artış
P – R aralığında uzaması
ST segment depresyonu

Tedavi

- Hafif vakalarda potasyum kaybına yol açan ilaçlar kesilir ve oral replasman yapılır
- Hafif kronik hipokalemide tedaviye ACEİ, ARB, spironolakton eklenebilir
- Kardiyak veya nörolojik komplikasyonlar ile potasyum düzeyinin <2.5 mEq/L'nin altında olduğu durumlarda ise intravenöz tedavi gereklidir

Tedavi

- Hazırlanan solüsyondaki potasyum konsantrasyonu 40 mEq/L'i geçmemeli, infüzyon hızı en fazla 10 mEq/L olmalıdır

- Daha yüksek hızda verilmesi gereken durumlarda santral kateter takılır ve maksimum 20 mEq/L hızından uygulanır

- Tedavi süresince sık aralıklarla potasyum düzeyleri ölçülür

Fosfor

- Kemik bileşimi
- Hücre membranı bileşimi
- Sinir iletimi
- Kas fonksiyonları
- ATP Sentezi
- Glukozun hücre içinde kullanılması ve glikoliz

Yoğun Bakım Hastasında Hipofosfatemi (Serum fosfor<2.7 mg/dl)

Klinik Etkileri

- Diafragma kasılmasında bozulma
- Akut solunum yetmezliği
- Doku hipoksisi
- Miyokard kasılmasında bozulma
- Paralizi, güçsüzlük
- Nörolojik fonksiyon bozukluğu

Yatkınlık yaratan Durumlar

- Malnutrisyon
- Vücut depolarındaki fosfor yetersizliği
- Respiratuar veya metabolik alkaloz
- Diyabetik ketoasidoz
- Alkolizm
- Gastrik kayıplar
- İlaçlar (insülin, diüretikler, anti-asitler, sükralfat)
- HD tedavileri
- Karbohidrattan zengin beslenme solusyonları

Yoğun Bakım Hastasında Hipofosfatemi-Tedavi

- Asemptomatik hafif hipofosfatemide
  - oral fosfat desteği
  - ishal yapabilir
  - potasyum veya sodyum tuzları halinde

- Semptomatik, ciddi hipofosfatemide
  - iv fosfat desteği
  - Doz belirleme ampirik

Yoğun Bakım Hastasında Hipofosfatemi-Tedavi

Empirical Treatment of Hypophosphatemia[129-135]

Serum Phosphorus Concentration (mg/dL)	I.V. Phosphate Replacement Dose (mmol/kg)[a,b]
2.3–2.7	0.08–0.16
1.5–2.2	0.16–0.32
<1.5	0.32–0.64

[a]In patients with normal renal function; patients with renal insufficiency should receive ≤50% of the initial empirical dose. Maximum infusion rate = 7 mmol phosphate per hour.

[b]The authors suggest using adjusted body weight (AdjBW) in patients who are significantly obese (weight of >130% of ideal body weight [IBW] or have a body mass index of ≥30 kg/m^2): AdjBW (men) = ([wt (kg) – IBW (kg)] × 0.3) + IBW; AdjBW (women) = ([wt (kg) – IBW (kg)] × 0.25) + IBW.

Yoğun Bakım Hastasında Hiperfosfatemi (Serum fosfor>4.5 mg/dl)

Nedenleri

- Kronik böbrek hastalığı
- Fosfat desteğinin fazla verilmesi
  (özellikle KBY hastalarında)
- Kolonoskopi hazırlığı sırasında fosfor içeriği yüksek laksatif kullanımı
- Respiratuar asidoz
- Metabolik asidoz
- Hemoliz
- Rabdomiyoliz
- Hipoparatiroidizm
- Vitamin D toksisitesi

Bulgular

- Hipokalsemi semptomları
  (kalsiyum-fosfor kristalleri)
- Tetani
- Konvülsiyon

Yoğun Bakım Hastasında Hiperfosfatemi (Tedavi)

- Hiperfosfateminin altta yatan nedeni tedavi edilmelidir

- Serum fosfor (N)
- Serum kalsiyum (N)
- CaXP < 55

Chapter 4.1: Treatment of CKD-MBD targeted at lowering high serum phosphate and maintaining serum calcium

4.1.1: In patients with CKD G3a–G5D, treatments of CKD-MBD should be based on serial assessments of phosphate, calcium, and PTH levels, considered together (*Not Graded*).

Rationale

The previous Recommendation 4.1.1 from the 2009 KDIGO CKD-MBD guideline gave treatment directions concerning serum phosphate levels in different GFR categories of CKD. The accumulated evidence on this issue to date is now depicted in Supplementary Tables S49–S51, S53–S55. Results of this evidence review can be summarized as follows: most studies showed increasing risk of all-cause mortality with increasing levels of serum phosphate in a consistent and direct fashion, with moderate risk of bias and low quality of evidence, thus not essentially different from the study results before 2009. For GFR decline and cardiovascular event rate, results were considered less conclusive.

Serum phosphate, calcium, and PTH concentrations are all routinely measured in CKD patients, and clinical decisions are often made based on these values. However, the results of these tests are influenced by food intake, adherence to and the timing of drug intake and dietary modifications, differences in assay methods and their intra-assay coefficient of variation (CV), and also by the interval from the last dialysis session in CKD G5D patients. Furthermore, it has recently been suggested that these markers undergo significant diurnal changes even in CKD patients.[35,36] Accordingly, the decision should be based not on a single result, but rather on the trends of serial results, which stands very much in accordance to 2009 Recommendation 3.1.4. In addition, recent *post hoc* analyses of large dialysis cohorts suggest that the prognostic implications of individual biochemical components of CKD-MBD largely depend on their context with regard to constellations of the full array of MBD biomarkers.[37] This analysis identified a wide range of CKD-MBD phenotypes, based on phosphate, calcium, and PTH measurements categorized into mutually

switching from "risk classes" parallels changes in incidence of complications or mortality over time. Of note, biomarkers such as bALP and 25(OH)vitamin D were also still considered valuable, but as no new evidence has been published on their account, recommendations remained unchanged from the previous guideline (2009 Recommendations 3.1.3, 3.2.3).

Finally, therapeutic maneuvers aimed at improving 1 parameter often have unintentional effects on other parameters, as exemplified by the recent EVOLVE trial.[38] The guideline Work Group considered it reasonable to take the context of therapeutic interventions into account when assessing values of phosphate, calcium, and PTH, and felt that it was important to emphasize the interdependency of these biochemical parameters for clinical therapeutic decision making.

Based on these assumptions, it was also decided to split previous 2009 Recommendation 4.1.1 into 2 new Recommendations, 4.1.1 (diagnostic recommendation based on accumulated observational evidence) and 4.1.2 (therapeutic recommendation based mostly on RCTs).

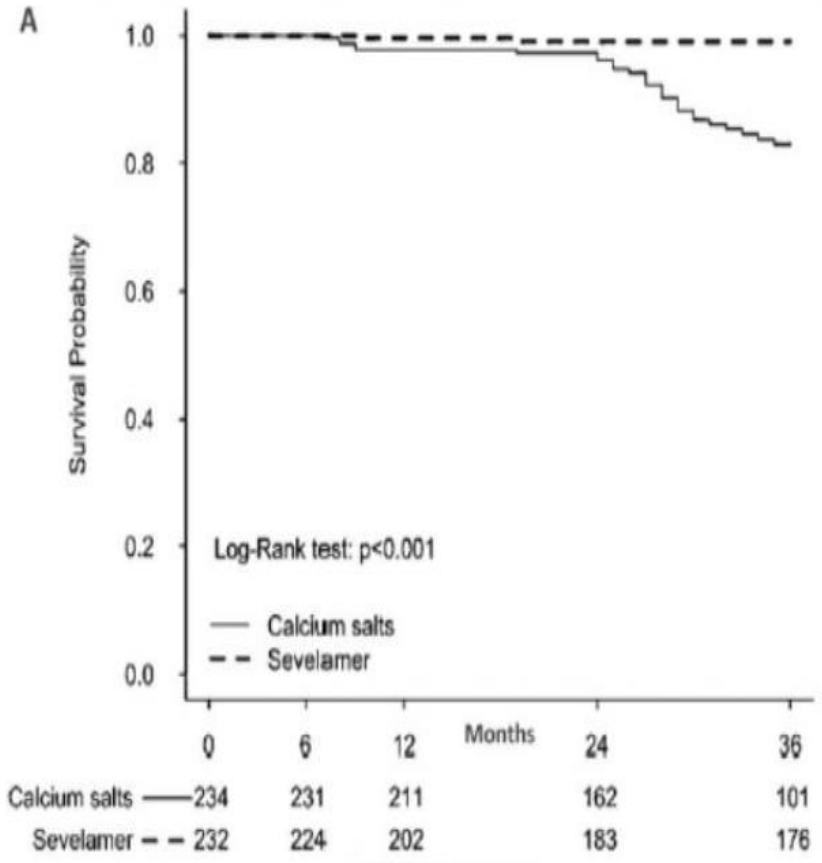
Research recommendations

- Prospective cohort studies or RCTs are needed to evaluate whether changes in CKD-MBD risk marker patterns over time associate with changes in risk (e.g., multiple interventions).
- Prospective cohort studies or RCTs are needed to examine whether biochemical abnormalities of CKD-MBD must be weighed differently when induced by pharmacotherapy compared with baseline values (e.g., past experience with hemoglobin as risk predictor vs. active treatment to targets by erythropoiesis-stimulating agents).
- Investigations contributing to the understanding of the usefulness of fibroblast growth factor 23 (FGF23) as a complementary marker for treatment indications (e.g., phosphate-lowering therapies to halt CKD progression) and direct treatment target (e.g., regression of left ventricular hypertrophy [LVH]) should be undertaken.

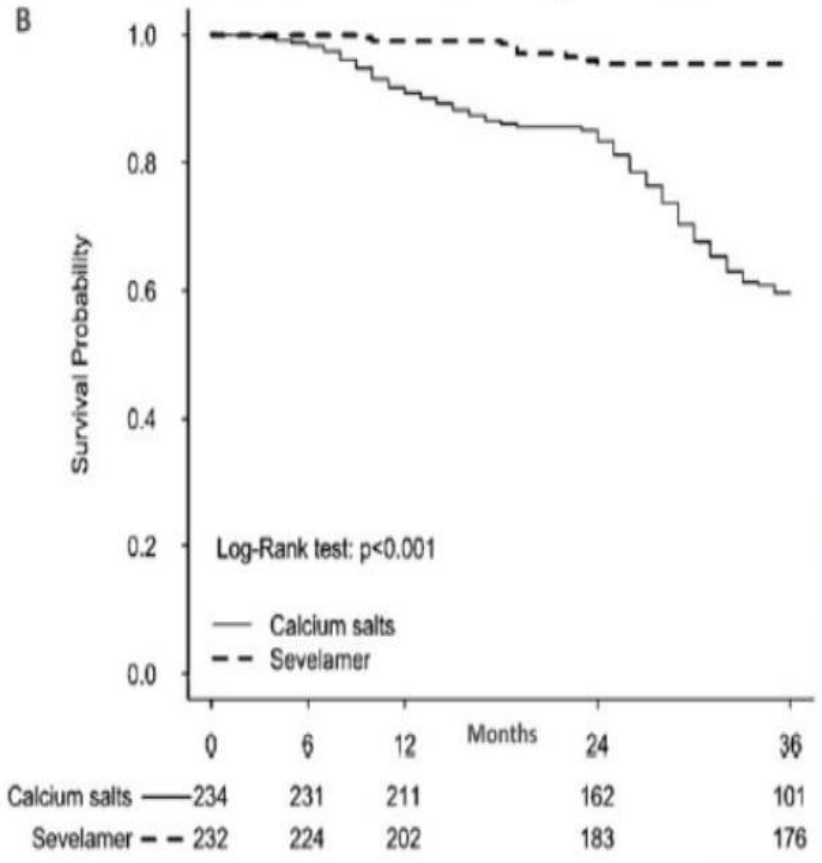
4.1.2: In patients with CKD G3a–G5D, we suggest lowering

SEVELAMER VS. CALCIUM

Arrythmias



Cardiovascular Mortality



Di Iorio B et al. Am J Kidney Dis. 2013;62:771-778

Kalsiyum

- Kemik metabolizması
- Kan pıhtılaşması
- Trombosit adhezyonu
- Kas fonksiyonları
- Kalp elektrofizyolojisi

Yoğun Bakım Hastasında Hipokalsemi (Serum kalsiyum<8.6 mg/dl, serum ionize kalsiyum<1.1mmol/l)

Nedenleri

- Hipoalbüminemi
- Hipomagnezemi
- Hiperfosfatemi
- Sepsis
- Pankreatit
- KBH
- Hipoparatiroidizm
- Eritrosit suspansiyonu

Bulgular

- Tetani
- Konvülsiyon
- Aritmi

Yoğun Bakım Hastasında Hipokalsemi-Tedavi

Empirical Dosages of I.V. Calcium[5,32,142]

Degree of Hypocalcemia	Preferred Calcium Salt[a]	Intermittent Bolus Dosage	Continuous Infusion Dosage[b]
Mild to moderate, asymptomatic	Gluconate	1–2 g calcium gluconate over 30–60 minutes; may repeat every 6 hours as needed	4.56–9.12 meq calcium over 30–60 minutes; may repeat every 6 hours as needed
Severe, symptomatic	Chloride or gluconate	1000 mg calcium chloride or 3 g calcium gluconate over 10 minutes; may repeat as needed	13.6 meq calcium over 10 minutes; may repeat as needed
Severe, symptomatic; refractory to intermittent bolus doses	Chloride or gluconate	Not applicable	0.8–1.5 meq calcium per minute; monitor serum calcium every 6 hours or more frequently

[a]Calcium chloride should be administered via a central venous catheter to avoid extravasation and tissue necrosis; 1000 mg calcium chloride = 13.6 meq calcium; 1 g calcium gluconate = 4.56 meq calcium.

[b]Maximum rate of intravenous infusion = 1.5 meq calcium per minute.

Yoğun Bakım Hastasında Hiperkalsemi (Serum kalsiyum>10.2 mg/dl)

Nedenleri

- Malignite
  - Meme ca
  - Akciğer ca
  - Multiple Miyelom
  - NHL
- Primer hiperparatiroidizm
- İlaçlar
  - tiyazid
  - lityum
- Vitamin D toksistesi
- Adrenal yetmezlik
- İmmobilizasyon

Bulgular

- Anoreksi
- Konfüzyon
- Bradikardi
- Aritmi
- Akut böbrek hasarı
- Nefrolitiasis
- Metastatik kalsifikasyon
- KBH

Yoğun Bakım Hastasında Hiperkalsemi-Tedavi

- İv hidrasyon + furosemid
- Bifosfonatlar (zolendronik asit, etidronat, pamidronat)
- Steroid
- Kalsitonin
- Sinakalset
- Denosumab
- Diyaliz

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Hypercalcemia in the Intensive Care Unit: A Review of Pathophysiology, Diagnosis, and Modern Therapy

Joshua D. Maier, MD[1] and Steven N. Levine, MD[2]

Abstract

Hypercalcemia may be seen in a variety of clinical settings and often requires intensive management when serum calcium levels are dramatically elevated. All of the many etiologies of mild hypercalcemia can lead to severe hypercalcemia. Knowledge of the physiologic mechanisms involved in maintaining normocalcemia and basic pathophysiology is essential for making a timely diagnosis and hence prompt institution of etiology-specific therapy. The development of new medications and critical reviews of traditional therapies have changed the treatment paradigm for severe hypercalcemia, calling for a more limited role for aggressive isotonic fluid administration and furosemide and an expanded role for calcitonin and the bisphosphonates. Experimental therapies such as denosumab show promise.

Keywords

hypercalcemia, hyperparathyroidism, malignancy-associated hypercalcemia, parathyroid hormone–related protein

Introduction

Hypercalcemia is a common clinical problem encountered in the routine practice of medicine. Although the number of potential causes of hypercalcemia is extensive, primary hyperparathyroidism and malignancy-associated hypercalcemia account for the vast majority of cases. Most patients will have relatively mild to moderate hypercalcemia not requiring admission to the hospital and only rarely will patients require treatment in a critical care unit. However, when severe, hypercalcemia can be life threatening, requiring prompt attention to reduce organ damage and mortality. Serum calcium levels exceeding 13 mg/dL are infrequently observed in those with primary hyperparathyroidism. Occasionally, a patient with a benign etiology of hypercalcemia can present with a parathyroid crisis, but when calcium levels are this high, malignancy-associated hypercalcemia or parathyroid carcinoma becomes the more likely diagnosis.

In this review, the pathophysiology and treatment of hypercalcemia will be discussed, focusing on those disorders that are likely to require management in a critical care unit.

maintaining a physiological concentration of calcium in these extraskeletal sites is essential for normal propagation of action potentials, muscular contraction, exocytosis of neurotransmitters and hormones, regulation of cell growth, activation of coagulation factors as well as regulation of numerous calcium-dependent enzymes.[1]

Calcium in blood exists in several forms. Approximately 50% of total serum calcium is protein bound, primarily to albumin, while a small proportion is complexed to anions such as phosphate and citrate. The remaining 45% to 50% is ionized, and only this ionized fraction is biologically active.[1,2] Most laboratories report total serum calcium levels. However, methods to measure ionized calcium are generally available for those in a critical care setting. A correction of the total serum calcium can be made by adjusting for deviations in the serum albumin level.[3] When calcium is expressed as milligram per

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Yoğun Bakım Hastasında Hipomagnezemi (Serum magnezyum<1.5 mg/dl)

Nedenler

- GIS kayıpları
- Renal kayıplar
- Sepsis
- Yanık
- Açlık/malnutrisyon
- Alkolizm
- İlaçlar
  - Tiyazidler
  - Furosemid
  - Aminıglikozidler
  - Amfoterisin B
  - Sisplatin
  - Siklosporin

Bulgular

- Aritmi (torsades de pointes)
- EKG değişiklikleri
- Konvülsiyon
- Koma
- Mekanik ventilasyon ihtiyacı

Yoğun Bakım Hastasında Hipomagnezemi-Tedavi

Empirical Treatment of Hypomagnesemia[42,45,166-173]

Severity	Serum Magnesium Concentration (mg/dL)	I.V. Magnesium Replacement Dose[a,b]
Mild to moderate	1.0–1.5	8–32 meq magnesium (1–4 g magnesium sulfate), up to 1.0 meq/kg
Severe	<1.0	32–64 meq magnesium (4–8 g magnesium sulfate), up to 1.5 meq/kg

[a]In patients with normal renal function; patients with renal insufficiency should receive ≤50% of the initial empirical dose. Maximum rate of infusion = 8 meq magnesium per hour (1 g magnesium sulfate per hour), up to 100 meq magnesium (approximately 12 g magnesium sulfate) over 12 hours if asymptomatic; up to 32 meq magnesium (4 g magnesium sulfate) over 4–5 minutes in severe symptomatic hypomagnesemia. 1 g magnesium sulfate = 8.1 meq magnesium.

[b]The authors suggest using adjusted body weight (AdjBW) in patients who are significantly obese (weight of >130% of ideal body weight [IBW] or have a body mass index of ≥30 kg/m^2): AdjBW (men) = ([wt (kg) – IBW (kg)] × 0.3) + IBW; AdjBW (women) = ([wt (kg) – IBW (kg)] × 0.25) + IBW.

Letter to the Editor

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Deficiencies of Magnesium Replacement in the Critically Ill

Klayton M. Ryman, PharmD[1] and Todd W. Canada, PharmD, BCNSP, BCCCP, FASHP, FTSHP[1]

Keywords
letter to the editor, magnesium deficiency, critical care, electrolyte replacement

Table 1. Continuous Magnesium (Mg) Infusions Over 24 Hours.

Author	N	Age, years	Male	Serum Creatinine (mg/dL)	Dose/Diluent Over 24 Hours	Serum Change (mEq/L)	mEq/L Rise/g Mg Given
Shechter et al[3]	96	66	65%	≤3	130 mEq/500 mL 5% Dextrose in Water	1.65-2.82	0.07
Raghu et al[4]	169	52.9	85%	≤3	146 mEq/100 mL 0.9% NaCl	1.3-3.6	0.11
Rasmussen et al[5]	56	64.6	70%	≤3	100 mEq/1000 mL 5% Dextrose in Water	1.5-2.46	0.08
Woods et al[6]	1159	61.4	74%	≤3.4	146 mEq/ 50 mL 0.9% NaCl	1.64-3.1	0.08

We read with interest the results from Hammond and colleagues assessing the "rule of thumb" for intravenous magnesium replacement based on the fact that every 1 g (8 mEq) of magnesium administered will increase the serum magnesium concentration by 0.15 mEq/L for critically ill patients with mild-to-moderate hypomagnesemia (1-1.9 mEq/L) within 18 to 30 hours.[1] Evaluation of empiric magnesium replacement strategies is important as it is a common practice in the critically ill but has limited studies to guide intermittent therapy until this important study.[1,2] The practice of magnesium replacement is largely based upon acute myocardial infarction trials (Table 1) administering an initial magnesium bolus (eg, 2 g [16 mEq]) followed by continuous infusions up to 16 g (130 mEq) over 24 hours.[3-6] The observed changes in serum magnesium concentrations have ranged from 0.07 to 0.11 mEq/L per gram of intravenous magnesium administered. Extrapolating these serum changes from continuous infusions of magnesium to lower doses (eg, 1-4 g) over 8 to 12 hours would be expected to have lower increases when rechecked up to 10 to 22 hours later (assuming 18-30 hours after dose). Although this study only included patients who met their empiric dosing strategy for mild-to-moderate hypomagnesemia, the dose of magnesium administered and how (eg, central vs peripheral venous access, diluent used, and duration of infusion) was not provided. could have also affected response to magnesium therapy. The use of proton pump inhibitors was not listed as an exclusion criteria and would be useful to know whether this may have affected magnesium response as it has been previously reported.[7] Evaluating the responses to electrolyte replacement, such as this one for magnesium in the ICU, may prove better ways to conserve electrolyte supplies, especially in the age of drug shortages for patients most likely to benefit.

Authors' Note

This manuscript is original research that has not been published and is not under consideration elsewhere. All authors have participated in the preparation of the manuscript. All authors had access to the data and participated in writing the manuscript.

References

1. Hammond DA, Stojakovic J, Kathe N, et al. Effectiveness and safety of magnesium replacement in critically ill patients admitted to the medical intensive care unit in an academic medical center: a retrospective, cohort study [published online July 13, 2017]. *J Intensive Care Med*. 2017. doi:10.1177/0885066617720631.

Yoğun Bakım Hastasında Hipermagnezemi (Serum magnezyum>2.4 mg/dl)

Nedenler

- KBH
- İatrojenik

Bulgular

- Bulantı-kusma
- Hipotansiyon
- DTR kaybı
- Bradikardi
- EKG değişiklikleri

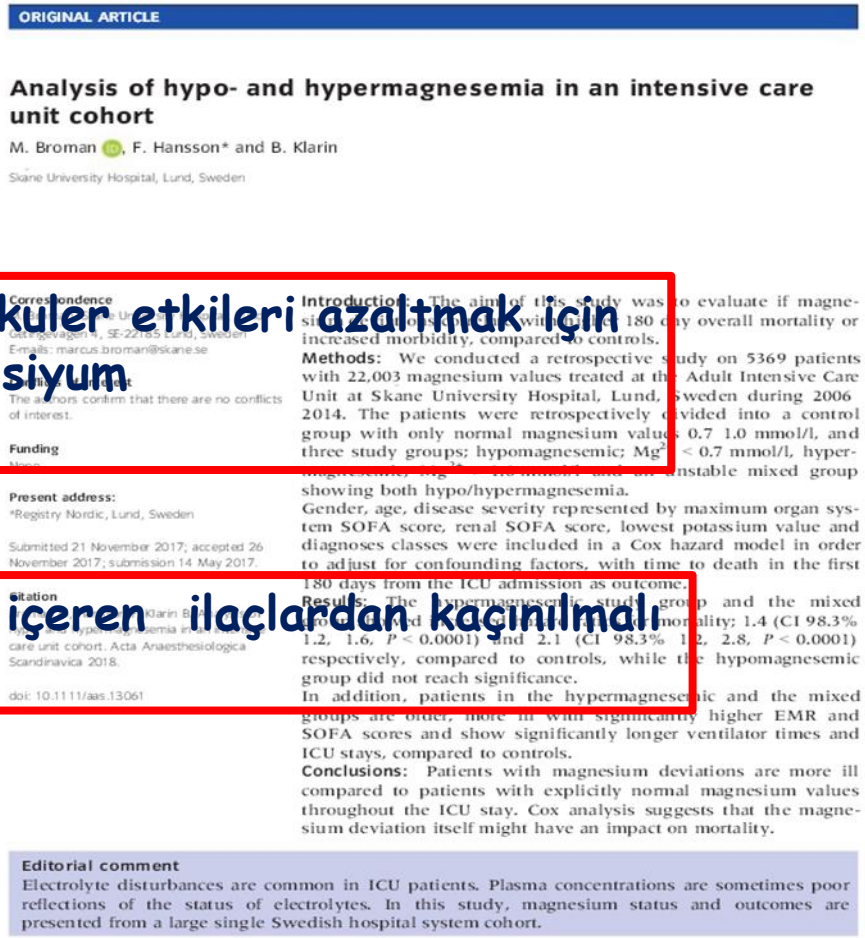
- Solunum depresyonu
- AV Blok
- Kardiyak arrest

Yoğun Bakım Hastasında Hipermagnezemi- Tedavi

- Magnezyum kısıtlama
- Furosemid
- Diyaliz

Kardiyovasküler ve nöromusküler etkileri azaltmak için İV kalsiyum

KBH larında magnezyum içeren ilaçlardan kaçınılmalı



ORIGINAL ARTICLE

Analysis of hypo- and hypermagnesemia in an intensive care unit cohort

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The authors confirm that there are no conflicts of interest.

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care unit cohort. Acta Anaesthesiologica Scandinavica 2018.

doi: 10.1111/aas.13061

Introduction: The aim of this study was to evaluate if magnesium [illegible] with 180 day overall mortality or increased morbidity, compared to controls.

Methods: We conducted a retrospective study on 5369 patients with 22,003 magnesium values treated at the Adult Intensive Care Unit at Skane University Hospital, Lund, Sweden during 2006 2014. The patients were retrospectively divided into a control group with only normal magnesium values 0.7 1.0 mmol/l, and three study groups; hypomagnesemic; Mg^{2+} < 0.7 mmol/l, hypermagnesemic; Mg^{2+} [illegible] and an unstable mixed group showing both hypo/hypermagnesemia.

Gender, age, disease severity represented by maximum organ system SOFA score, renal SOFA score, lowest potassium value and diagnoses classes were included in a Cox hazard model in order to adjust for confounding factors, with time to death in the first 180 days from the ICU admission as outcome.

Results: The hypermagnesemic study group and the mixed [illegible] mortality; 1.4 (CI 98.3% 1.2, 1.6, $P < 0.0001$) and 2.1 (CI 98.3% 1.2, 2.8, $P < 0.0001$) respectively, compared to controls, while the hypomagnesemic group did not reach significance.

In addition, patients in the hypermagnesemic and the mixed groups are older, more ill with significantly higher EMR and SOFA scores and show significantly longer ventilator times and ICU stays, compared to controls.

Conclusions: Patients with magnesium deviations are more ill compared to patients with explicitly normal magnesium values throughout the ICU stay. Cox analysis suggests that the magnesium deviation itself might have an impact on mortality.

Editorial comment
Electrolyte disturbances are common in ICU patients. Plasma concentrations are sometimes poor reflections of the status of electrolytes. In this study, magnesium status and outcomes are presented from a large single Swedish hospital system cohort.