The Development and Implementation of Evidence-Based Electrolyte Replacement Guidelines in the Intensive Care Unit

Robert MacLaren, Kirk B. Ramsay, Margaret T. Liiva, Katherine A. Connell, Graeme M. Rocker, and Richard I. Hall

INTRODUCTION

The goal of evidence-based medicine (EBM) is to identify interventions that optimize patients' therapies and outcomes by integrating clinical expertise with the systematic review and objective interpretation of the literature.[1,2] Unfortunately, implementing EBM interventions is often limited by the time required to disseminate information and by lack of adherence by health-care professionals and patients.[3-5] These limitations may be alleviated by the development of national or international consensus guidelines or the use of institution-specific protocols that direct interventions.[4-9] Examples of evidence-based, institution-specific protocols involving the intensive care unit (ICU) include the pharmacologic management of continuous sedation,[10-16] analgesia,[15,16] neuromuscular blockade,[16,17] and prophylaxis of stress ulcer.[18] This article describes the development and implementation of EBM guidelines for electrolyte replacement therapy in the ICU.

BACKGROUND

At the Queen Elizabeth II Health Sciences Centre in Halifax, NS, there are 2 medical/surgical ICUs with a combined 24-bed complement. One ICU also provides care for neurologic and trauma patients. Resident physicians from various disciplines are directed by 1 of 7 attending physicians, who rotate weekly to provide care to ICU patients. The attending physicians represent the disciplines of anesthesia, surgery, respirology, and general medicine.

Although pharmacy and dietary services have been present clinically in the ICUs for several years, dosing for electrolyte replacement varied according to physician practice. Several problems were evident, including incomplete repletion, multiple doses, unnecessary measurements of serum electrolyte concentrations, and excessive administration of fluid, which occasionally necessitated diuretic therapy. Potassium chloride and sodium phosphate were frequently administered independently for the treatment of hypokalemia and hypophosphatemia, when one product, potassium phosphate, could have been used to replace both electrolytes. Moreover, the nurses administering the electrolytes frequently followed the instructions in an institution-based intravenous drug manual. Originally developed to facilitate the safe administration of intravenous medications to all patients, regardless of hospital location, this manual was perceived by many ICU health-care professionals as representing practice standards. Unfortunately, the recommendations in the manual are not intended specifically for the ICU and are not evidence-based.

As a result of concerns about electrolyte replacement, the multidisciplinary members of the Critical Care Program Quality Assurance Committee decided to develop evidence-based treatment guidelines for electrolyte replacement, specifically potassium, phosphate, and magnesium. The goal was to provide these guidelines to all health-care professionals working in the medical/surgical ICUs to facilitate appropriate dosing and measurement of serum concentrations, to reduce adverse consequences, and to possibly generate economic savings. A 3-member subcommittee, comprising 2 pharmacy representatives (R.M., K.B.R.) and 1 dietary representative (M.T.L.), was given the mandate of developing dosing guidelines for electrolyte replacement.

PROTOCOL DEVELOPMENT

An English-language search of MEDLINE (for the period 1967 to 1998) and InPharma (for the period 1981

to 1998) was conducted using paired MeSH terms (Medical Subject Headings) for key-word and text-word identification of potassium, hypokalemia, magnesium, hypomagnesemia, phosphate, hypophosphatemia, electrolyte, critical care, replacement, and repletion. All citations involving humans were retrieved and the bibliographies reviewed to obtain pertinent articles not identified in the original search. Abstracts of critical care, nutrition, and pharmacy conferences were reviewed to obtain unpublished data. Because none of the trials identified was randomized, methodologic quality was not evaluated. Each member of the subcommittee informally assessed all review articles and studies for information relevant to the patients admitted to our ICUs. The members of the subcommittee met to discuss the articles and to formulate rough drafts for dosing guidelines for each electrolyte. All members of the Critical Care Program Quality Assurance Committee reviewed the rough drafts, and discrepancies, concerns, and questions were discussed among the members.

Once the guidelines were complete, they were sent to a select multidisciplinary group of ICU personnel for constructive criticism. Some concerns arising as a result of this review included "higher-than-expected doses" for magnesium and phosphate replacement, the need for clarification of "normal renal function", absence of a guideline for calcium replacement, and controversy surrounding the application of these guidelines as practice standards. As a result, the guidelines were modified to reduce the maximum dose of magnesium and prolong the duration of phosphate administration. Although these modifications deviated from EBM, the members of the committee agreed that these changes would likely facilitate implementation of the protocols by preventing similar concerns among other ICU staff. The term "normal renal function" was replaced by a calculation of creatinine clearance. An EBM guideline for calcium replacement was developed on the basis of concurrent serum phosphate concentration according to the same process as was used for the other electrolytes. The guidelines were further modified so that they could be used as practice standards for electrolyte replacement in the medical/surgical ICUs of our institution. These modifications included the addition of administration information. As well, asterisks were added to help ensure that bedside nurses evaluated questions or concerns specific to the electrolyte being replaced. Dosage adjustments for creatinine clearance were added in tabular form for potassium, phosphate, and magnesium so that the physician could order "replace electrolyte according to protocol". The bedside nurse could then determine the appropriate dose for that electrolyte after assessing the patient's renal function. The revised protocols were redistributed to the original group of ICU personnel because they differed substantially from the original guidelines, and they were accepted with only minor changes for clarification (see Appendix 1 for final versions of the guidelines).[19-31]

To assess the protocols for effectiveness and safety before they became policy, resident physicians in both medical/surgical ICUs were given copies of the protocols and asked to use them for a period of 1 month. The nurses were then educated about the protocols and the limitations of using creatinine clearance to assess renal function. They were asked to use the protocols for a short-term trial in a cohort of patients. However, during the initial education sessions and before the trial period, the nurses expressed concerns about the authoritative and legal responsibilities of replacing electrolytes according to protocols. As a result, the members of the Critical Care Program Quality Assurance Committee revoked their decision to use these guidelines as practice standards. Instead, the guidelines were printed as a double-sided laminated pocket card and were given to health-care professionals in the medical/surgical ICUs. Therefore, each guideline served as a reference rather than as a practice standard or policy, and physicians were permitted to deviate from the guidelines at their discretion. The entire process of developing the guidelines took approximately 1 year.

EXPERIENCE WITH THE GUIDELINES

Although the guidelines have not been formally evaluated, a number of practice changes were observed during the development and implementation phases. Overall, there appears to be enhanced awareness among ICU staff of the importance of electrolyte replacement. For all electrolytes, replacement doses are now generally higher, which has resulted in fewer doses and less fluid to replenish serum electrolytes. This change in practice was evident during the trial period for the resident physicians, when the clinical pharmacists were frequently paged by the bedside nurses about doses that appeared excessive or that were inadequately diluted. On rare occasions, the distributive pharmacist entering the order into the patient profile contacted the bedside nurse to verify the order or to suggest administering the dose in a larger volume of fluid than what had been ordered. Although we are unable to objectively assess the guidelines' impact on the number of tests ordered to determine serum electrolyte levels, samples for these tests are typically drawn 6 to 8 h after the dose is given, which thus provides time for distribution of the electrolyte. Since implementation of these guidelines, potassium phosphate is being administered frequently,

which has resulted in more efficient repletion of both electrolytes. The increased use of potassium phosphate has resulted in requests from several bedside nurses to supply it as ward stock in the medical/surgical ICUs. Although implementation is continuous as resident physicians rotate and nursing staff changes over time, several physicians, pharmacists, and dieticians outside the ICU have requested copies of the protocols.

DISCUSSION

Enhanced patient care, reduced costs, and staff education have been documented with the implementation of institution-specific EBM protocols for the management of continuous sedation,[10-16] analgesia,[15,16] neuromuscular blockade,[16,17] and prophylaxis of stress ulcer.[18] Observations by the ICU staff at our hospital suggest that implementation of EBM guidelines for electrolyte replacement in our medical/surgical ICUs may have influenced practice by providing a method of maintaining consistent therapy. However, it is important to remember that EBM is a new concept for many health-care professionals. Although most personnel now support the electrolyte replacement guidelines, the need for the guidelines was often questioned during the education sessions. Therefore, for successful implementation of EBM, it is imperative to meet frequently with personnel to explain the reasons for developing the guidelines and the process of implementation. Constructive criticism should be encouraged, and multidisciplinary consensus is required. The process of implementing EBM guidelines is an ideal educational opportunity for all ICU personnel.[32-34] All health-care professionals need to be reminded that guidelines are not comprehensive, and certain situations may require deviations. One individual should be designated to ensure that guidelines are revised as new information becomes available.

On the basis of this experience, several recommendations can be made regarding implementation of evidence-based guidelines. It is important to determine the goal of the specific guideline early in the process, to effectively communicate this goal to as many staff as possible, and to establish a means by which the guideline will be evaluated. For example, during the development phase of our protocols the nursing staff provided early identification of the concern about liability.

The development of guidelines in the ICU facilitates the process of EBM, providing education and optimizing therapy. Considerable multidisciplinary cooperation and communication are required for successful implementation of guidelines.

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Robert MacLaren, PharmD, was, at the time of this project, a Critical Care Specialist, Department of Pharmacy, Queen Elizabeth II Health Sciences Centre, Halifax, NS. He is now with the School of Pharmacy, University of Colorado Health Sciences Center, Denver, Colo.

Kirk B. Ramsay, BSc, is a Pharmacy Student, College of Pharmacy, Dalhousie University, Halifax, NS.

Margaret T. Liiva, CNSD, PDt, is a Clinical Dietitian, Department of Food and Nutrition Services, Queen Elizabeth II Health Sciences Centre, Halifax, NS.

Katherine A. Connell, BScN, RN, is a Critical Care Clinical Nurse Educator, Department of Nursing, Queen Elizabeth II Health Sciences Centre, Halifax, NS.

Graeme M. Rocker, MA, DM, FRCP, FRCPC, is Director of the Medical/Surgical Intensive Care Unit, Victoria General Site, Queen Elizabeth II Health Sciences Centre, Halifax, NS.

Richard I. Hall, MD, FRCPC, FCCP, is Director of Intensive Care Services, Queen Elizabeth II Health Sciences Centre, Halifax, NS.

Address for correspondence:
Dr Rob MacLaren
School of Pharmacy
University of Colorado Health Sciences Center
4200 East Ninth Avenue
Denver CO
80262
e-mail: rob.maclaren@uchsc.edu

Acknowledgement
Supported by funds available through the Dalhousie University College of Pharmacy Research Endowment Fund.

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Appendix 1. Electrolyte Replacement Guidelines for Adult Patients in the Medical/Surgical Intensive Care Units of Queen Elizabeth II Health Sciences Centre

Required dose adjusted according to calculated creatinine clearance (CrCl):

$$\text{CrCl (mL/min)} = \frac{(140 - \text{age [yr]}) \times \text{IBW [kg]} \times 60}{\text{SCr(mol/L)} \times 50}$$ (if female, result of calculation is multiplied by 0.85)

For intravenous replacement, check electrolyte level 6 h after completion of each dose.

SCr = serum creatinine, IBW = ideal body weight, D5W = dextrose 5% in water, FPS = Fleet phospho-soda.

Guideline for replacement of potassium[19-21]*

Electrolyte Deficiency	Enteral			IV – Peripheral			IV – Central		
	CrCl < 25 mL/min	CrCl 25–50 mL/min	CrCl > 50 mL/min	CrCl < 25 mL/min	CrCl 25–50 mL/min	CrCl > 50 mL/min	CrCl < 25 mL/min	CrCl 25–50 mL/min	CrCl < 50 mL/min
Mild 3.1–3.6 mmol/L	20 mEq bid	40 mEq bid	80 mEq bid	Nil	20 mEq	40 mEq	Nil	20 mEq	40 mEq
Moderate 2.5–3.0 mmol/L	Enteral replacement not recommended			20 mEq	40 mEq	60 mEq	20 mEq	40 mEq	60 mEq
Severe or emergency‡ (notify MD) < 2.5 mmol/L	Enteral replacement not recommended			40 mEq	60 mEq	80 mEq	40 mEq	60 mEq	80 mEq
Administration information	Available as 20 mEq/15 mL KCl solution			Available as 2 mEq/mL KCl (10- and 20-mL vials). Doses < 40 mEq may be diluted in 100 mL NaCl or D5W but doses of ≥ 40 mEq should be diluted in 250 mL NaCl or D5W. Preferred rate < 10 mEq/h (max rate for emergency use = 20 mEq/h). Max dose = 200 mEq/24 h.			Available as 2 mEq/mL KCl (10- and 20-mL vials). Doses ≤ 40 mEq may be diluted in 100 mL NaCl or D5W but doses > 40 mEq should be diluted in 250 mL NaCl or D5W. Preferred rate < 20 mEq/h (max rate for emergency use = 40 mEq/h). Max dose = 400 mEq/24 h.		

*Check most recent phosphate level before deciding on salt form.
‡Check magnesium level.

Guideline for replacement of phosphate[22-25]

Electrolyte Deficiency	Enteral			IV – Peripheral or Central*		
	CrCl < 25 mL/min	CrCl 25–50 mL/min	CrCl > 50 mL/min	CrCl < 25 mL/min	CrCl 25–50 mL/min	CrCl > 50 mL/min
Mild 0.60–0.89 mmol/L	16–32 mmol bid	16–32 mmol tid	16–32 mmol qid	Nil	0.16 mmol/kg (max dose = 15 mmol)	0.16 mmol/kg (max dose = 30 mmol)
Moderate 0.40–0.59 mmol/L	Enteral replacement not recommended			0.16 mmol/kg (max dose = 15 mmol)	0.24 mmol/kg (max dose = 30 mmol)	0.32 mmol/kg (max dose = 45 mmol)
Severe or emergency (notify MD) <0.39 mmol/L	Enteral replacement not recommended			0.24 mmol/kg (max dose = 30 mmol)	0.32 mmol/kg (max dose = 45 mmol)	0.64 mmol/kg (max dose = 60 mmol)
Administration information	Available as phosphate Novartis 500-mg tablets (equivalent to 16 mmol phosphate; contains 20.4 mEq Na and 3.1 mEq K) or 26 mmol/5 mL FPS solution (contains 33 mEq Na)			Available as potassium phosphate (5-mL vial = 15 mmol phosphate, 22 mEq K) and sodium phosphate (10-mL vial = 30 mmol phosphate, 40 mEq Na). Use potassium phosphate if serum K < 4.0 mmol/L. Dose is based on *actual body weight* and is adjusted to nearest *increment* of 7.5 mmol. Doses ≤ 30 mmol may be diluted in 100 mL NaCl or D5W but doses > 30 mmol should be diluted in 250 mL NaCl or D5W. Max rate = 7.5 mmol/h. Max dose = 80 mmol/24 h.		

*Doses ≥ 30 mmol: obtain serum calcium level and phosphate level 6 h after dose.

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Appendix 1. Electrolyte Replacement Guidelines for Adult Patients in the Medical/Surgical Intensive Care Units of Queen Elizabeth II Health Sciences Centre ... continued

Guideline for replacement of magnesium[26-29]

Electrolyte Deficiency	Enteral			IV – Peripheral or Central		
	CrCl < 25 mL/min	CrCl 25–50 mL/min	CrCl > 50 mL/min	CrCl < 25 mL/min	CrCl 25–50 mL/min	CrCl > 50 mL/min
Mild 0.55–0.70 mmol/L	245 mg q day	245 mg bid	245 mg qid	Nil	2 g	4 g
Moderate 0.40–0.54 mmol/L	Enteral replacement not recommended			2 g	4 g	6 g
Severe or emergency (notify MD) <0.39 mmol/L	Enteral replacement not recommended			4 g	6 g	8 g
Administration information	Available as magnesium oxide 420-mg tablets (245 mg elemental Mg) and magnesium glucoheptonate solution 100 mg/mL (5.12 mg/mL elemental Mg)			Available as magnesium sulphate (2-mL vial = 4 mmol = 1 g, 10 mL = 20 mmol = 5 g). Doses ≤ 4 g may be diluted in 100 mL NaCl or D5W but doses > 4 g should be diluted in 250 mL NaCl or D5W. Preferred rate = 0.5–1 g/h (max rate for emergency use = 4 g/h). Max dose = 16 g/24 h.		

Guideline for replacement of calcium[30,31]

Electrolyte Deficiency	Enteral			IV – Peripheral or Central		
	Phosphate < 2.0 mmol/L	Phosphate 2.0–3.0 mmol/L	Phosphate > 3.0 mmol/L	Phosphate < 2.0 mmol/L	Phosphate 2.0–3.0 mmol/L	Phosphate > 3.0 mmol/L
Mild (asymptomatic) 0.80–0.99 mmol/L	400 mg bid	Notify MD to correct phosphate		Nil; notify MD to correct phosphate		
Mild (symptomatic) 0.80–0.99 mmol/L	Enteral replacement not recommended	Enteral replacement not recommended; notify MD to correct phosphate		180 mg = 20 mL calcium gluconate 10% or 6.7 mL CaCl 10%	Notify MD to correct phosphate; 90 mg = 10 mL calcium gluconate 10% or 3.3 mL CaCl 10%	Notify MD to correct phosphate
Moderate 0.60–0.79 mmol/L	Enteral replacement not recommended	Enteral replacement not recommended; notify MD to correct phosphate		270 mg = 30 mL calcium gluconate 10% or 10 mL CaCl 10%	Notify MD to correct phosphate; 90–180 mg	Notify MD to correct phosphate; 90 mg
Severe or emergency (notify MD) <0.59 mmol/L	Enteral replacement not recommended	Enteral replacement not recommended; notify MD to correct phosphate		360 mg = 40 mL calcium gluconate 10% or 13.3 mL CaCl 10% (repeat until symptoms controlled)	Notify MD to correct phosphate; 180–270 mg	Notify MD to correct phosphate; 90–180 mg
Administration information	Available as calcium carbonate = Tums 500-mg tablets (200 mg elemental Ca)			Available as calcium gluconate 10% (10-ml ampoule = 90 mg elemental Ca = 2.25 mmol) and CaCl 10% (10-mL syringe or ampoule = 270 mg elemental Ca = 6.75 mmol). Doses should be diluted in 250 mL NaCl or D5W. Preferred rate = 30 mg/h (max rate for emergency use = 90 mg/h). Max dose = 720 mg/24 h.		