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Comparison of Nasogastric and Intravenous Methods of Rehydration in Pediatric Patients With Acute Dehydration

Alan L. Nager, MD, FAAP, and Vincent J. Wang, MD

ABSTRACT. *Objective.* **To assess the safety, efficacy, and cost-effectiveness of rapid nasogastric hydration (RNG) and rapid intravenous hydration (RIV) administered in the emergency department (ED) to young children suffering with uncomplicated, acute moderate dehydration.**

Methods. **Ninety-six children aged 3 to 36 months, who presented with signs and symptoms of uncomplicated, acute moderate dehydration caused by vomiting and/or diarrhea, presumed to be caused by viral gastroenteritis, were randomly assigned to receive either RNG with a standard oral rehydration solution or RIV with normal saline. Each solution was administered at a rate of 50 mL/kg of body weight, delivered over a 3-hour period in our urban pediatric ED. All participants were weighed pretreatment and posttreatment and underwent initial and final measurements of their serum electrolytes, blood urea nitrogen, creatinine, and glucose levels, along with urine chemistry and urine specific gravity. Telephone follow-up by completion of a standardized questionnaire was obtained approximately 24 hours after discharge from the ED.**

Results. **Ninety-two of 96 enrolled patients completed the study. Three patients failed treatment (2 RIV and 1 RNG) and were excluded and hospitalized because of severe, intractable vomiting, and 1 patient was withdrawn secondary to an intussusception. Among 92 evaluable patients, 2 were found to be severely dehydrated (>10% change in body weight) and were excluded from analysis, leaving 90 patients (RNG: $N = 46$ and RIV: $N = 44$), who completed the study. Both RNG and RIV were found to be a safe and efficacious means of treating uncomplicated, acute moderate dehydration in the ED. Determinations of electrolytes, blood urea nitrogen, creatinine, or glucose were not found to be of value on an intent-to-treat basis in the care of these patients. The urine specific gravity and incidence of ketonuria declined from levels commensurate with moderate dehydration in the RNG group, but not as consistently so in the RIV group. Both RNG and RIV were substantially less expensive to administer than standard care with intravenous fluid deficit therapy in-hospital, and RNG was more cost-effective to administer over RIV in the outpatient setting.**

Conclusion. **RNG and RIV administered in the ED are safe, efficacious, and cost-effective alternatives to the standard treatment for uncomplicated, acute moderate dehydration in young children. RNG is as efficacious as RIV, is no more labor intensive than RIV, and is associated with fewer complications. In addition, we found that most routine laboratory testing is of little value in these patients and should be avoided, except when clearly clinically indicated.** *Pediatrics* **2002;109:566–572;** ***pediatric, dehydration, oral rehydration therapy, nasogastric hydration, gastroenteritis.***

ABBREVIATIONS. IV, intravenous; ORT, oral replacement therapy; ED, emergency department; RNG, rapid nasogastric hydration; RIV, rapid intravenous hydration; CHLA, Childrens Hospital Los Angeles; NG, nasogastric; UTI, urinary tract infection; OFC, oral fluid challenge; BUN, blood urea nitrogen; SG, specific gravity.

Acute gastroenteritis complicated by dehydration remains a major cause of morbidity around the world and, in some developing countries, a major cause of mortality.[1–3] Historically, dehydration accompanying acute gastroenteritis has been treated by hospitalization and intravenous (IV) fluid replacement therapy in both adults and children.[4] In the United States, 1 pediatric report estimated that 220 000 admissions (9% of all admissions) and 400 deaths occur annually.[3] As early as the mid-1960s, fluid replacement therapy was managed in developing countries by oral replacement therapy (ORT) with a standardized, mildly hypotonic oral replacement solution, often administered in an outpatient setting.[1] In 1972, Hirschorn et al[5,6] demonstrated that a hypotonic oral replacement solution could be safely and effectively used on an outpatient basis to rehydrate children with mild-to-moderate dehydration. Children fared well even in the presence of significant hyponatremia, hypernatremia, hypokalemia, hyperkalemia, or metabolic acidosis. In addition, outpatient ORT is more easily administered and much less costly than standard IV therapy.[1,3] Since 1985, the American Academy of Pediatrics has recommended that mild-to-moderate dehydration accompanying acute gastroenteritis be treated by ORT with hypotonic solutions of sodium (Na), potassium (K), and glucose in the outpatient setting.[7] However, despite numerous studies showing that outpatient ORT is safe and equally as effective as IV therapy, even for moderately to severely dehydrated children,[1,8–11] physicians in developed countries have often resisted administering outpatient ORT, preferring instead to hospitalize even mildly dehydrated children for IV therapy.[12,13] Much of the basis for this resistance is founded in the common impres-

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sion that outpatient ORT is either too labor-intensive, slow, or inconvenient to the family to be an acceptable alternative to IV rehydration in-hospital.[2,3,14–16]

In this study, we hypothesized that young children suffering from acute symptoms of vomiting and/or diarrhea, presumed to be caused by acute gastroenteritis, accompanied by moderate dehydration, could be successfully treated in the emergency department (ED) over a period of 3 hours. This could be accomplished by using a standard oral replacement solution by means of either rapid nasogastric hydration (RNG) or rapid intravenous hydration (RIV). In addition, we hypothesized that RNG would be equally safe, effective, and durable as RIV, and that the use of RNG in the ED would be associated with significant cost savings over RIV in this same setting.

METHODS

Study Population

Childrens Hospital Los Angeles (CHLA) is a large, urban, pediatric, tertiary care teaching hospital that also serves the primary care needs of children in Los Angeles. The annual number of visits per year is approximately 50 000, with about 3000 per year presenting with vomiting and/or diarrhea. Between October 1997 and March 1999, a prospective, random, convenience sample of children aged 3 to 36 months were enrolled if they had acute complaints of vomiting and/or diarrhea and were determined by 1 of the study investigators (A.L.N. or V.J.W.) to be moderately dehydrated. In addition, these children were unable to tolerate oral fluids sufficient to overcome their dehydration. Informed consent was obtained from the caregivers of all patients. This study was approved and monitored by the institutional review board of CHLA.

Definitions

Vomiting and/or diarrhea were considered acute in onset if the symptoms had been present for less than or equal to 7 days in duration. Assessment of dehydration, (Table 1) was used to estimate clinical parameters of dehydration.[7] Patients were excluded because of severe dehydration (>10%), intractable vomiting or shock, suspected intussusception, appendicitis, malrotation, recent trauma, meningitis, congestive heart failure, or if evidence of these diagnoses appeared as the study progressed. Patients were also excluded if they had any of the following significant chronic diseases: chronic lung disease, congenital heart disease, gastroesophageal reflux, renal insufficiency, diabetes mellitus, seizure disorder, any neurologic cause of increased intracranial pressure, severe anemia, or history of bleeding diathesis, sickle cell disease, malignancy, or chronic inflammatory disease.

Capillary refill time was defined as the amount of time for vascular reperfusion after blanching pressure was applied to the nailbed and was used as an adjunct to determine dehydration.[17] Hypoglycemia was defined as a serum glucose level <50 g/dL. The degree of fluid deficit found among study participants was analyzed by comparison of pretreatment and posttreatment weights to ascertain the degree of dehydration among study participants.[17]

Complications were defined as hematemesis or hematochezia, complications of IV catheter or nasogastric (NG) tube placement, and emesis during the rehydration period. Emesis was included as a complication, because NG tube placement may be complicated with emesis. Complications of IV catheter placement included multiple attempts to place the IV catheter, extravasation of IV fluids into the subcutaneous tissue, and inadvertent displacement of the IV catheter before treatment was completed. Complications of NG tube placement included epistaxis, multiple attempts to place the NG tube, placement of the tube into the trachea, or inadvertent displacement of the tube before treatment was completed.

Pathogens isolated from stool were considered significant if they were *Shigella*, *Salmonella*, or *Campylobacter* species. Urinary tract infection (UTI) was considered present if *Escherichia coli*, *Staphylococcus aureus*, *Klebsiella* species, or *Proteus* species had grown as a single organism ≥100 000 colonies per high-powered field.

Study Design

Before study commencement on each patient, an oral fluid challenge (OFC) was attempted. If the patient vomited, drank an insufficient amount to overcome their dehydrated state, or refused liquids, as observed by 1 of the study investigators, enrollment was pursued. Patients were randomized to receive rapid rehydration over a 3-hour period either via a NG tube or via an IV catheter. Patients randomized to RNG hydration underwent placement of a flexible, silastic, 5 French feeding tube, after applying Cetacaine (Cetylite Industries, Inc, Pennsauken, NJ; benzocaine, butyl aminohydrate, tetracaine hydrochloride) spray/gel to the nose and throat. After obtaining clinical confirmation of the position of the feeding tube, these patients received a continuous NG infusion of 50 mL/kg of Pedialyte (Ross Products Division, Abbott Laboratories, Columbus, OH) over a 3-hour period. Patients who vomited at least 3 times after institution of RNG hydration were switched to conventional IV hydration therapy and were considered treatment failures. Patients randomized to the RIV arm received a continuous infusion of 50 mL/kg of normal saline IV over a 3-hour period, after placement of either a 22- or 24-gauge IV catheter. The volume of fluid given was determined based on the average, accepted volume given to ED patients with moderate dehydration, sufficient enough to avoid hospitalization and alleviate the acute dehydrated state. In contrast, patients requiring >50 mL/kg of fluid in the ED are generally admitted to the hospital for additional rehydration therapy. All NG and IV placement procedures were performed by experienced ED nursing staff.

All children were weighed (on 1 scale calibrated daily), and underwent blood and urine studies pretreatment and posttreatment, including serum sodium (Na), potassium (K), chloride (Cl), bicarbonate (CO_2), blood urea nitrogen (BUN), creatinine (Cr), urine chemistry and specific gravity (SG). In addition, all patients were tested for hypoglycemia and treated as necessary with 2 mL/kg of D10W or D10NS before commencing rehydration therapy. Stool cultures for common bacterial pathogens were obtained

TABLE 1. Determination of Dehydration

Variable	Mild (3%–5%)	Moderate (6%–9%)	Severe (>10%)
Blood pressure	Normal	Normal	Normal to reduced
Quality of pulses	Normal	Normal or slightly decreased	Moderately decreased
Heart rate	Normal	Increased	Increased*
Skin turgor	Normal	Decreased	Decreased
Fontanelle	Normal	Sunken	Sunken
Mucous membranes	Slightly dry	Dry	Dry
Eyes	Normal	Sunken orbits	Deeply sunken
Extremities	Normal capillary refill	Delayed capillary refill	Cool, mottled
Mental status	Normal	Normal to listless	Lethargic or comatose
Urine output	Slightly decreased	<1 mL/kg/h	<1 mL/kg/h
Thirst	Slightly increased	Moderately increased	Very thirsty

* Bradycardia may appear in severe cases.
Adapted from Duggan et al.[25]

from all those presenting with diarrhea. Other testing (including urine culture), was obtained when clinically indicated, as determined by the treating attending physician. Patients were monitored during rehydration by nursing staff with hourly assessments of their vital signs, intake, and output (including emesis, urine, and stool volumes, which were measured in a beaker or on a "diaper" scale), general clinical state, capillary refill time, and the development of any complications. At the end of the 3-hour rehydration period, all patients in both study groups were immediately given an OFC, and had posttreatment studies performed 30 minutes later. Patients were discharged from the hospital if they tolerated an OFC, had normal vital signs for age, normal tearing, moist oral mucosa, normal capillary refill times, and demonstrated an average urine output of at least 0.5 mL/kg during the study period. All other patients were hospitalized and their charts individually reviewed on follow-up within 24 hours. Telephone follow-up by completion of a standardized questionnaire was obtained approximately 24 hours after discharge from the ED for patients sent home. These patients were encouraged to return to the ED if, at the discretion of 1 of the study investigators (A.L.N.), signs and symptoms of dehydration appeared to recur or persist, or otherwise, at the discretion of the caregivers. Patients who were contacted after discharge, appeared well without evidence of dehydration on telephone interview, and did not return to the ED, were assumed to have recovered completely.

Cost Analysis

Aggregate and per patient costs for laboratories, supplies, and nursing time were assessed from CHLA's usual charge basis for both treatment arms. The extent of any savings to be expected at CHLA from using RNG by this protocol instead of ordering RIV in the ED was determined.

Statistical Analysis

Sample size estimates, demonstrated that when 44 participants were enrolled in each of RIV and RNG groups, a difference in failure rates of 20% or more would reveal an 80% chance of being detected, at $\alpha = 0.05$ 1-sided level of significance.[20] Analysis of variance was performed to determine group characteristics. Fisher exact test was used to test for differences in binary response variables between RNG and RIV groups, and χ^2 analysis was used to test for association between groups for multiple categorical variables. Paired t test within RNG and RIV groups were performed on initial and final measures when the difference was normally distributed. If normality was not valid, the nonparametric Wilcoxon signed rank test was used. Two group t tests were performed between RNG and RIV groups for initial and final measures when the data were normally distributed. Wilcoxon rank sum or Mann-Whitney U nonparametric tests were used when the data were nonnormal. Normally distributed data were presented as mean ± standard deviation. Nonnormally distributed data were presented as median and range. Statistically significant differences were defined as P values of less than .05 (2-tailed, if applicable). Data were key-entered and verified using Teleform Verifier (Cardiff Software Inc, San Maros, CA),[21] and then validated and analyzed using SAS 6.12 Statistical Software (SAS Institute Inc, Cary, NC).[22]

RESULTS

Patients

During the study period, 475 patients presented to the ED with uncomplicated dehydration resulting from acute symptoms of vomiting and/or diarrhea. A total of 96 patients meeting the study criteria were enrolled, of which 1 withdrew (RNG) because he was later found to have an intussusception. Three patients (2 RIV and 1 RNG), were excluded during the study period because of severe, intractable vomiting and admitted to an observation unit as treatment failures (3% of enrolled), and excluded from additional analysis. All 3 of these patients were later discharged after successful overnight rehydration using standard IV therapy. Two additional patients (RIV group) were excluded from the analysis because of severe dehydration, as measured by percentage body weight gained after therapy (>10% body weight). The remaining 90 patients were divided between the RNG ($N = 46$) and RIV ($N = 44$) arms. These groups were similar with respect to gender, ethnic self-identification (predominantly Hispanic), duration of symptoms, number of episodes of vomiting and/or diarrhea, presence or absence of tearing and abnormal capillary refill times, and their ultimate diagnoses (92% of cases were attributable to viral gastroenteritis). Four patients were diagnosed with bacterial enteritis; *Shigella* and *Campylobacter* species were isolated from 2 RIV patients, and *Shigella* was isolated from 2 RNG patients. In addition, 2 patients (1 RIV and 1 RNG) were diagnosed with an *E coli* UTI, and 1 RNG patient had a UTI with *Klebsiella pneumoniae.* The study groups did differ with respect to mean age, 13 months (RNG) versus 16 months (RIV; $P = .02$).

Safety, Efficacy, and Patient Tolerance of RNG Versus RIV

Placement of the NG tube failed in 2 patients (4.3% mean per case failure rate), requiring a second attempt at placement (1 patient pulled out the tube and 1 had minor nasal bleeding after the first insertion). In contrast, IV catheterization failed frequently, requiring 27 additional attempts among 13 of the 44 evaluable RIV patients (61.4% mean per case failure rate; $P < .0001$). One patient required treatment of hypoglycemia in accordance with the study protocol (RNG, glucose = 45 g/dL), and there were no clinically significant complications of fluid therapy in either group. Pulse was elevated in both groups with a mean initial pulse of 138 (RNG: 138 ± 17, RIV: 137 ± 15; $P = .72$) and showed a parallel improvement in both groups with a mean final pulse of 126 (RNG: 126 ± 16, RIV: 126 ± 14; $P = .91$). There were no statistically significant differences in other vital signs, including temperature, respiratory rate, or blood pressure among or between the groups, either before, during, or after therapy.

Comparison Between RNG and RIV Groups

Among evaluable subjects in the RNG group, the average participant weighed 9.55 kg and gained 220 g after treatment. This did not differ significantly from the RIV group, where the average patient weighed 10.07 kg and gained 350 g. However, as a percentage of body weight, the RNG group gained less than the RIV group (RNG: 2.21% body weight vs RIV: 3.58% body weight; $P = .0077$). Both patients who gained >10% body weight were in the RIV group and were removed from analysis. When examined as a percentage of the pretreatment weight, there was no statistically significant difference between the study groups as to total intake or individually as to output of emesis, urine, or stool. However, episodes of emesis were more common in the RNG group (vs RIV; $P = .0284$) and associated with a slightly greater nominal measured emesis volume.

Mean initial and final laboratory values for the 2 study groups as a whole (excluding 2 patients who

TABLE 2. Mean Laboratory Values

Test		RNG	RIV	*P* Value	RNG ($n = 46$) Initial Versus Final	*P* Value	RIV ($n = 44$) Initial Versus Final	*P* Value
Na (mmol/L)	Initial	141 ± 3.4	142 ± 3.3	NS	2.02 ± 0.36	<.001	−0.30 ± 0.30	<.001
	Final	139 ± 3.2	142 ± 2.7	<.001				
K (mmol/L)	Initial	4.6 ± 0.09	4.7 ± 0.010	.008	−0.22 ± 0.08	.008	0.28 ± 0.51	<.001
	Final	4.7 ± 0.10	4.5 ± 0.65	<.001				
Cl (mmol/L)	Initial	106 ± 4.3	107 ± 5.0	NS	1.4 ± 0.45	.003	−3.91 ± 0.52	<.001
	Final	105 ± 3.7	111 ± 4.0	<.001				
CO_2 (mmol/L)	Initial	15.2 ± 2.9	14.9 ± 3.0	NS	−1.8 ± 0.40	<.001	0.14 ± 0.36	<.001
	Final	17.0 ± 3.4	14.7 ± 2.4	<.001				
AG (mmol/L)	Initial	19.5 ± 3.5	19.6 ± 3.1	NS	2.4 ± 0.45	<.001	3.40 ± 0.53	<.001
	Final	17.1 ± 2.9	16.1 ± 3.7	NS				
BUN (mmol/L)	Initial	10 (21)*	10 (47)*	<.001	2 (21)*	<.001	1 (47)*	<.001
	Final	8 (19)*	9 (36)*	<.001				
Cr (mg/dL)	Initial	0.4 (0.5)*	0.4 (0.4)*	NS	0.1 (0.6)*	<.001	0.1 (0.5)*	<.001
	Final	0.3 (0.6)*	0.3 (0.4)*	NS				
Glucose (gm%)	Initial	84 ± 17.4	89 ± 20.9	NS	1.07 ± 1.90	NS	12.7 ± 2.55	<.001
	Final	83 ± 13.9	76 ± 12.9	.010				
Ur SG (%>1.025)	Initial	60.9	75.0	NS	50.0 ± 9.0	<.001	43.2 ± 9.6	<.001
	Final	10.9	31.8	.02				
Ur Ketones (%+)	Initial	65.2	77.3	NS	21.7 ± 10.1	NS	−4.6 ± 8.6	NS
	Final	43.5	81.8	<.001				

NS indicates not significant.
Anion gap (AG) = Na − (Cl + CO_2), rounded to the nearest 0.1 mmol.
* Median or difference in medians (range).

had gained >10% body weight), are presented in Table 2. For most laboratory tests studied, there were statistically significant but clinically insignificant differences between the study groups for final laboratory values. In the RNG group, the CO_2 level increased after therapy to 17.0 ± 3.4 mmol/L (vs initial; $P < .001$) whereas in RIV patients, the mean initial CO_2 level decreased slightly with therapy. Although 31 (67%) RNG patients experienced an improvement in their CO_2 level after therapy, this outcome was reversed in RIV patients, whereas 19 (43%) experienced an improvement and 21 (48%) experienced a decline in their CO_2 level ($P < .001$). The mean BUN level was within the normal range and declined with therapy in both groups ($P < .001$). The mean initial urine SG was elevated to 1.025 or above in the majority of patients and did not differ between groups. However, although the mean final urine SG declined in both groups, the decline was greater for the RNG group (mean: 1.012) than the RIV group (mean: 1.019; vs RNG; $P < .001$). The mean final urine SG was >1.025 in 10.9% of RNG patients, whereas 31.8% of RIV patients continued to show a urine SG >1.025 ($P = .02$). Finally, ketonuria was initially present in 65.2% of RNG patients and 77.3% of RIV patients and did not differ significantly between them; however, only 20 (43.5%) RNG patients continued to manifest ketonuria at the final examination, whereas 36 (81.8%) RIV patients did so (vs RIV; $P < .001$).

Durability of Treatment Effect

All study patients were discharged from the hospital. On telephone follow-up of 90% of both groups, using a standardized questionnaire, there were no statistically significant differences found in the incidence of persistent emesis, persistent diarrhea, absent urination, absent tear production, moistness of the mucous membranes, or rate of reevaluation in the ED within 24 hours of discharge. Of the 8 reevaluated RNG patients (return rate: 18%), all were seen at CHLA. Five tolerated an OFC and 3 received conventional IV fluid therapy in the ED after failing an OFC (typical pattern of treating moderately dehydrated patients in our ED). All of these patients were discharged from the hospital. Of the 7 reevaluated RIV patients (return rate: 15%), 6 were seen at CHLA. All patients tolerated an OFC and were discharged from the hospital without the need for additional IV therapy. One additional RIV patient (on telephone follow-up) was evaluated at an outside institution and likewise given an OFC and discharged from the hospital. No statistically significant differences were found for RIV or RNG patients who returned to the ED for reevaluation, $P = .78$.

Relative Cost-Effectiveness of RNG Therapy

Laboratory study charges averaged $309 per patient for both groups. The average per patient cost of necessary supplies common to both treatment groups was $109. The average per patient cost of additional supplies specific to each treatment arm was $190 for the RIV group and $73 for the RNG group. The Pedialyte used by the RNG group was donated to CHLA for this study but was generally available for between $4 and $6 per liter. The average per patient cost of the estimated nursing time necessary for each treatment arm was the same. In addition, the additional per patient cost incurred as a result of attempting to restart failed intravenous lines averaged $13.04 for the RIV group, whereas the per patient cost incurred as a result of reinserting failed NG tubes averaged $0.43 for the RNG group. Allowing for the saved cost of Pedialyte, the total applicable per case cost of care was, thus, $642.64 for the RIV group and $525.90 for the RNG group, which represents a per case savings of $116.74 (18.2%) over the RIV group. The annualized total cost of care for the

total of 475 patients evaluated in the ED during the study period, had they been treated by RIV, would have been about $305 254 and about $249 803 if treated by RNG. This represents a difference of $55 451.

DISCUSSION

With the ever-increasing imperative of managed care to reduce costs and increase the efficiency and efficacy of patient care, our study provides evidence that young, otherwise normal children suffering from moderate dehydration in the setting of acute vomiting and/or diarrhea can be safely and effectively treated by ORT administered by the technique of RNG. Also, RNG is at least as safe and effective as the use of rapid IV hydration, and offers substantial cost savings over RIV.

The administration of ORT by NG tube has always been available in circumstances where the mild to moderately dehydrated child refuses to drink, is unable to tolerate ORT because of persistent vomiting, or where there is concern about the family's ability to participate in delivering ORT.[10] However, very few studies have attempted to directly and rigorously compare the benefits of ORT administered by NG with traditional IV therapy for such children. Sharifi et al[9] demonstrated in a randomized, prospective trial that NG ORT was equally effective as IV therapy in 470 children hospitalized in Tehran in 1981 with moderate-to-severe dehydration. Some of these patients had severe dehydration and signs of shock. Only 1 patient was considered a treatment failure in their study group ($N = 236$). Rosegger and Sixl[8] successfully treated moderately dehydrated infants and young children with ambulatory NG ORT at 15 mL/kg over a 3-hour period ($N = 40$) and combined NG and IV rehydration in severely dehydrated children in-hospital ($N = 30$) in Southern Sudan in 1983. Green[10] demonstrated in 1987 in the Democratic Republic of Congo that NG ORT could safely and effectively rehydrate moderately to severely dehydrated children, but over a period of 25 hours in most cases. Gremse's study[15] of mildly dehydrated hospitalized patients, performed in Alabama between 1991–1993, corroborates the findings of these earlier studies. He showed that 11 of 12 patients were safely and effectively rehydrated with a NG method. In all but the study by Rosegger et al, NG ORT was given over the same time course as traditional IV therapy and in an inpatient setting. Mackenzie and Barnes[18] compared oral and intravenous rehydration, but the findings of this study are limited by the study design, which permitted children in the IV therapy group to drink ORS. Also, not all children in the oral therapy group received NG ORT. More recently, several studies have shown that children suffering with acute gastroenteritis accompanied by mild to moderate dehydration can safely and effectively be treated with RIV in an inpatient or outpatient setting.[11–13] Patients may receive RIV over periods as little as 3 to 6 hours, followed by the early reinstitution of a normal diet supplemented with ORT to replace on-going diarrheal losses. Indeed, Holliday et al[12] has suggested that the traditional deficit therapy approach is outmoded, and should be abandoned in favor of ORT in mildly to moderately dehydrated patients, and RIV among those severely dehydrated.

Comparison of Safety and Effectiveness

We found that administering ORT by RNG in the ED was well-tolerated and associated with no greater failure rate than ORT, generally, nor with any greater failure rate than RIV. The 1 patient withdrawn from the RNG group was withdrawn for purposes of analysis and only after completing his therapy. His intussusception was not clinically apparent at the time the decision to treat was made, and it is highly unlikely that his treatment with RNG caused the intussusception. Indeed, RNG at the rate of 50 mL/kg over 3 hours was not associated with any significant clinical complications. On the other hand, RIV was complicated by repeated catheter insertions in a substantial minority of patients. These complications added to the inconvenience and pain in these patients and to the overall cost of their care.

Our findings indicate that, on every measure studied, the quality of the hydration provided by administering a standard, commercially available oral rehydration solution by means of RNG over a 3-hour period was equally as good as that offered by RIV over this same time period, and was no more labor-intensive based on tasks performed. The average RIV patient experienced no overall improvement in serum bicarbonate levels and ketonuria during the study period, and a minority actually experienced a worsened metabolic acidosis during this time, notwithstanding a clearly positive fluid balance and a mean weight gain of 350 g in this group. RNG patients, on the other hand, experienced an improvement in metabolic acidosis, urine concentration, and ketonuria during the study period with no clear difference in the amount of weight gained. We used normal saline as the RIV infusate instead of lactated Ringer's solution, as other researchers have done.[6,9,12,19] It is possible that the relative failure of our RIV patients to correct their metabolic acidosis and ketonuria during the study period is attributable to the lack of bicarbonate in the resuscitation fluid. Similarly, our RIV patients experienced a statistically significant, but clinically insignificant, decline in serum glucose, which may be attributable to the lack of glucose in the resuscitation fluid. Overall, the best indicator of dehydration among our patients was the urine SG. It was initially measured above 1.025 in the majority of patients and fell commensurately with therapy in both groups. It dropped to a normal level (<1.015) in the majority of RNG patients by the end of therapy, but lagged behind among RIV patients. This finding, and the greater clearance of ketonuria among RNG patients, suggests that RNG may provide, overall, a higher quality of rehydration than RIV in the same setting.

The treatment of these young, moderately dehydrated children (the vast majority with acute gastroenteritis) in the ED, in lieu of hospitalizing them, succeeded by either RNG or RIV. The predominant belief among clinicians, despite our assumptions,

was that RIV hydration would be dramatically more successful than the RNG method, especially in patients with vomiting. We were able to discern, however, a difference of only 2% in failure rates (RNG: 43 of 44, 98%; RIV: 44 of 46, 96%) between groups. Both methods of treatment for these moderately dehydrated children in the ED resulted in durable and clinically acceptable outcomes in almost every patient, notwithstanding the relatively minor laboratory differences between the 2 groups after therapy. The 3 treatment failures were each hospitalized for IV therapy and overnight observation and were discharged from the hospital in good condition. The 2 patients who, retrospectively, were severely dehydrated were each successfully treated with RIV and released from the ED and did not return. Although 15 (17%) of 90 evaluated patients returned to the ED within 24 hours for reevaluation, none were admitted to the hospital, and 87% of these were successfully treated with additional ORT. Thus, both RNG and RIV succeeded in reducing the need for hospitalization of children with acute gastroenteritis and moderate dehydration with acceptable outcomes by both methods. In addition, on telephone follow-up, all parents of study participants unanimously acknowledged acceptance of the method used on their child, even RNG, which was an unfamiliar method of rehydration to most parents.

Relationship of Dehydration and Weight Gain

It has been written that clinical estimation of acute dehydration may overestimate the actual degree of dehydration, as judged by the percentage weight gain after treatment from the presumed premorbid weight.[17,18] In our study, patients in RIV and RNG groups gained on average only 285 g, suggesting mild dehydration. Clinically, however, patients in both groups uniformly appeared moderately dehydrated based on the Duggan criteria, on specific laboratory determinations, and on clinical improvement. The lower percentage weight gain occurred principally because of a greater total output of emesis, urine, and stool. As in our study, careful assessment and recording of intake and output, along with changes in weight (pretreatment and posttreatment), may be a more accurate means of estimating a child's fluid deficit than the overall change in body weight solely. Furthermore, future investigations might consider obtaining a nonsick baseline weight (such as from a well-child visit) and a posttreatment weight when the child is symptom free and well hydrated, along with recorded losses, to more accurately assess dehydration and clinical improvement.

Laboratory Testing and Cost-Effectiveness

Gremse found that the use of NG rehydration in-hospital for similarly situated children was associated with a reduction in the mean per patient per diem cost of hospitalization from $1064 to $870 (18% less).[15] Because NG rehydration was also associated with a shortened mean length of stay from 2.8 days to 1.8 days (36%), therapy via RNG hydration reduced the overall per patient cost of hospitalization from $2831 to $1318, or a 53% reduction. Although this was not determined in our study, by extrapolation, if RNG had been used in the outpatient setting instead of hospitalization for these patients, the overall per patient cost of care could theoretically have been reduced from $2831 to only $595, representing a 79% reduction.

Considerable controversy has existed over the value of preadmission laboratory testing among these children.[18,19,23,24] Some of these authors have advocated the use of the BUN or serum urate levels as a proper measure of dehydration, while others have not found any support for this and, instead, have advocated serum bicarbonate measurements. However, in each of these studies, little or no attempt was made to obtain accurate measurements of body weight gain, intake, and output during the study period. Although our results show that BUN, creatinine, urine SG, and the incidence of ketonuria all declined, and serum bicarbonate rose, as expected, with the treatment of moderate dehydration by RNG; these results were not as consistent with treatment by RIV. Moreover, aside from the decline in urine SG and ketonuria, the laboratory changes we detected were trivial or not immediately clinically relevant. Indeed, such changes may be deemed "self-correcting," with treatment of the underlying dehydration.[12] Although this was not an apriori hypothesis, we found that the level and change in the urine SG and presence of ketonuria with treatment are the best laboratory indicators of moderate dehydration and the effectiveness of treatment, and that, in general, electrolytes, BUN/Cr and glucose testing may be avoided, except where clearly clinically indicated, or in patients suspected of having severe dehydration.

If this recommendation were followed by obtaining only a simple urine dip stick, and if the serum electrolytes, BUN/Cr and cultures which we routinely performed for the purpose of this study were avoided, an additional mean savings of $302.70 per case in laboratory costs could have been obtained, and the overall cost of care per case for these young, moderately dehydrated children with acute gastroenteritis could have been reduced to $223.20 (65% over RIV, 92% over hospitalization). Although these figures are necessarily only theoretical, and actual cost savings may vary greatly with the cost structure of each institution at which such care is provided, these figures demonstrate the great savings to be achieved—CHLA could have saved $1 238 705 per year on the care of these patients during the study period.

Limitations of Study

Determining weights of patients was problematic given the nature of young children and the inherent desire to move, especially when placed on a small scale. Every effort was made to assure calibration of the scale and to determine before and after weights when the child was as still as possible. In addition, the ultimate diagnosis was not uniform (viral gastroenteritis), as a small number of patients had bacterial enteritis and UTI. We specifically chose to test for bacterial stool pathogens and UTI because these dis-

eases may require antibiotics and additional follow-up. Although the occurrence of such diseases probably did not affect outcome or the ability to handle fluid replacement, nonetheless diagnostic consistency was not obtained on all patients studied. Also, differences in improvement, and in laboratory results for study participants in RIV and RNG groups, may have arisen because of solutes given: hypotonic, glucose solution versus normal saline. Although telephone follow-up by a standardized questionnaire seemed appropriate, not all patients were contacted. In addition, verbal instead of in-person follow-up may not be as accurate. And some patients, after discharge from the ED could have sought additional treatment elsewhere, thus possibly affecting reevaluation outcome.

CONCLUSION

RNG hydration may be safely and effectively used in children suffering from moderate dehydration caused by acute symptoms of vomiting and/or diarrhea, presumed to be from acute gastroenteritis. RNG is as efficacious as RIV, is no more labor intensive than RIV, and is associated with fewer complications. In addition, we found that most routine laboratory testing is of little value in these patients and should be avoided, except when clearly clinically indicated. The utilization of RNG also results in significant cost savings as compared with RIV and standard IV therapy. RNG may be used in place of RIV in the ED or possibly in an alternative "well-equipped" outpatient setting.

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