Population-Based Incidence of Potentially Life-Threatening Complications of Hypocalcemia and the Role of Vitamin D Deficiency

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Objectives To determine the incidence of potentially life-threatening complications of hypocalcemia in infants and children in Olmsted County, Minnesota; and to determine if vitamin D deficiency contributed to these events and was, at the time of clinical presentation, considered as a possible cause.

Study design In this population-based descriptive study, data were abstracted from the Rochester Epidemiology Project, a medical record linkage system covering 95% of patients in Olmsted County, Minnesota. Participants were children aged 0-5 years who resided in Olmsted County between January 1, 1996 and June 30, 2017, and who received diagnoses of seizures, cardiomyopathy, cardiac arrest, respiratory arrest, laryngospasm, and/or tetany. The incidence of hypocalcemia plus a potentially life-threatening complication was calculated.

Results Among 15 419 patients aged 0-5 years in Olmsted County during the study period, 1305 had eligible complications: 460 had serum calcium checked within 14 days of presentation and 85 had hypocalcemia. Patients were excluded when causes other than hypocalcemia likely triggered the complication, leaving 16 children whose complication was attributed to hypocalcemia. Three of these 16 patients had a serum 25-hydroxyvitamin D measurement and 2 were deficient (≤6 ng/mL [15 nmol/L]). Among children aged 0-5 years, the incidence of hypocalcemia plus a potentially life-threatening complication was 6.1 per 100 000 person-years (95% CI, 3.5-10.0).

Conclusions Vitamin D deficiency is an underinvestigated cause of complications of hypocalcemia in children. Serum calcium and 25-hydroxyvitamin D should be measured in children with these complications to identify possibly life-threatening vitamin D deficiency. *(J Pediatr 2019;211:98-104)*.

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Humans obtain vitamin D primarily from solar ultraviolet B (UVB) radiation, dietary supplements, and fortified foods and infant formulas.[1-3] Inadequate nutrition and negligible sun exposure cause serum 25-hydroxyvitamin D [25(OH)D] values of ≤20 ng/mL (50 nmol/L),[4] a concentration associated with an increased risk of the clinical consequences of vitamin D deficiency, in 1 billion people worldwide.[1,2] Sufficient vitamin D enhances dietary calcium absorption by 30%-40%.[1] Vitamin D deficiency, in contrast, can cause hypocalcemia and manifest as rickets, with leg deformities, stunted growth, and swelling of wrists and ankles.[1,5,6] The frequency of nutritional rickets has increased in ethnic minority populations in Europe and North America in recent years.[7] The incidence of nutritional rickets in children <3 years of age in Olmsted County, Minnesota, was relatively steady from 1970 to 2000, but increased substantially after 2000.[8] Ionized calcium is integral to cardiomyocyte contractility, and hypocalcemic-dilated cardiomyopathy and cardiac arrest may occur with sustained hypocalcemia.[9-15] Hypocalcemic seizures and tetany can ensue during periods of rapid growth, especially during infancy.[9,11,16-18] Stridor, laryngospasm, and apnea have been associated with vitamin D deficiency.[17,19,20] Hence, vitamin D deficiency increases the risk of morbidity and mortality, especially among at-risk infants.

Although the complications of hypocalcemia are well-understood, it is unclear how frequently vitamin D deficiency causes life-threatening hypocalcemia or is routinely considered in patients with these complications. Our primary objective was to determine the population-based incidence of hypocalcemia associated with seizures, cardiomyopathy, cardiac arrest, respiratory arrest, laryngospasm, and/or tetany in children aged 0-5 years in Olmsted County, Minnesota. Additional objectives were to determine if vitamin D deficiency contributed to these

25(OH)D 25-hydroxyvitamin D

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events and was, at the time of clinical presentation, considered as a possible cause; to assess patterns of race, ethnicity, time of year, breastfeeding status, and other risk factors in patients with hypocalcemic complications; and to describe the outcomes of mortality and morbidity of children with hypocalcemic complications.

Methods

We conducted a population-based descriptive study in Olmsted County, Minnesota, using the database of the Rochester Epidemiology Project. The Rochester Epidemiology Project database is a population-based medical record linkage system that includes >50 years of health care use, diagnostic, and laboratory data from virtually all medical providers in Olmsted County, Minnesota, covering 98% of all health care services provided for Olmsted County residents.[21,22] The county is served by 2 large integrated health systems, the Mayo Clinic and the Olmsted Medical Center.[23] More than 95% of the Olmsted County population has granted authorization for their records to be used for research.[24,25]

Olmsted County, Minnesota, is located in the upper Midwestern US (44°N latitude) and has limited sun exposure in winter. The population has increased from 135 897 to 148 700 between 2002 and 2011. In the 2000 and 2010 censuses, the proportions of residents classified as white, black, Asian, and Hispanic were 90% and 85.7%, 2.7% and 4.8%, 4.3% and 5.4%, and 2.4% and 4.2%, respectively. The proportions of individuals <5 years of age were 7.2% and 7.5%, respectively. Compared with the entire US 2010 population, the county is less ethnically diverse (86% vs 72% white), more educated (94% vs 85% high school graduates), and wealthier ($64 090 vs $51 914 median household income). However, characteristics of the population are very similar to the overall population of the upper Midwest.[25]

Children aged 0-5 years who resided in Olmsted County between January 1, 1996, and June 30, 2017, and who received diagnoses of seizures, cardiomyopathy, cardiac arrest, respiratory arrest, laryngospasm, and/or tetany were eligible for inclusion. We collected data regarding each patient's date of birth, sex, and self-reported race and ethnicity. The diagnoses of seizure, cardiomyopathy, cardiac arrest, respiratory arrest, laryngospasm, and tetany were based on *International Classification of Diseases 9th and 10th edition* codes (**Table I**; available at www.jpeds.com). We recorded the date of diagnosis, patient age at diagnosis, date of first symptoms, and length/height and weight percentiles nearest to the date the patient presented with the reported complication (index date). The serum total calcium, ionized calcium, and albumin values closest to the index date and the lowest value within 14 days (before/on/after) of the index date were all recorded. We recorded serum 25(OH)D, alkaline phosphatase, and phosphorus measurements closest to the index date within 6 months. We determined the number of days from index date to treatment date for hypocalcemia and vitamin D deficiency and the type of treatment patients received. Radiographs were evaluated for evidence of rickets. Finally, we determined whether the patient had a diet of exclusively breastmilk or formula, or a combination of both immediately before the index date.

The clinical data were adjudicated by 3 clinicians, and patients were excluded from the study cohort if causes other than hypocalcemia were more likely to have triggered the complication. Other reasons for exclusion included patients who had not given prior authorization to retrospective chart review for research purposes, being born at ≤37 weeks of gestation and the index date was the date of birth, the diagnosis code pulled was not applicable to the study, surgical complications, index date of ≤3 days after birth, congenital anomalies, infection, and trauma.

The study was approved by the Mayo Clinic Institutional Review Board, and all included records had research authorization for retrospective chart review.

Statistical Analyses

Continuous variables were summarized using means and standard deviations, and categorical variables were summarized using frequencies and percentages. Age- and sex-adjusted incidence rates per 100 000 persons in Olmsted County were calculated using the number of persons with a complication fitting inclusion criteria as the numerator and age- and sex-specific person-years of the population of Olmsted County aged 0-5 for 1996-2017 as the denominator (population count obtained from the decennial US census for Olmsted County with linear interpolation between census years, each person was counted as contributing an entire person-year of observation). The 95% CIs were calculated assuming a Poisson error distribution. Race-specific incidence calculations use the race-specific information from the US census from Olmsted County for the denominator counts and person-year calculations. Comparison of incidence was done using generalized linear regression modeling with a Poisson error. All analyses were performed using SAS version 9.4 (SAS Institute Inc, Cary, North Carolina).

Results

Between January 1, 1996, and June 30, 2017, 1305 of 15 419 patients aged 0-5 years in Olmsted County had eligible life-threatening complications. Specifically, 930 patients had seizures, 338 had cardiac arrest, 105 had respiratory arrest, 75 had laryngospasm, 66 had cardiomyopathy, and 2 had tetany. Among these patients, 460 (35%) had a serum calcium level measurement and 85 (18.5% of patients with a serum calcium level measured) had a serum calcium below the laboratory reference range for pediatric patients (total calcium of <8.8 mg/dL [2.2 mmol/L] or ionized calcium of <3.7 mg/dL [0.93 mmol/L])[26] (**Figure 1**; **Table II**).

One hundred eighty-four patients had 2 complications (14.1%), 11 had 3 complications (0.8%), and 2 had 4

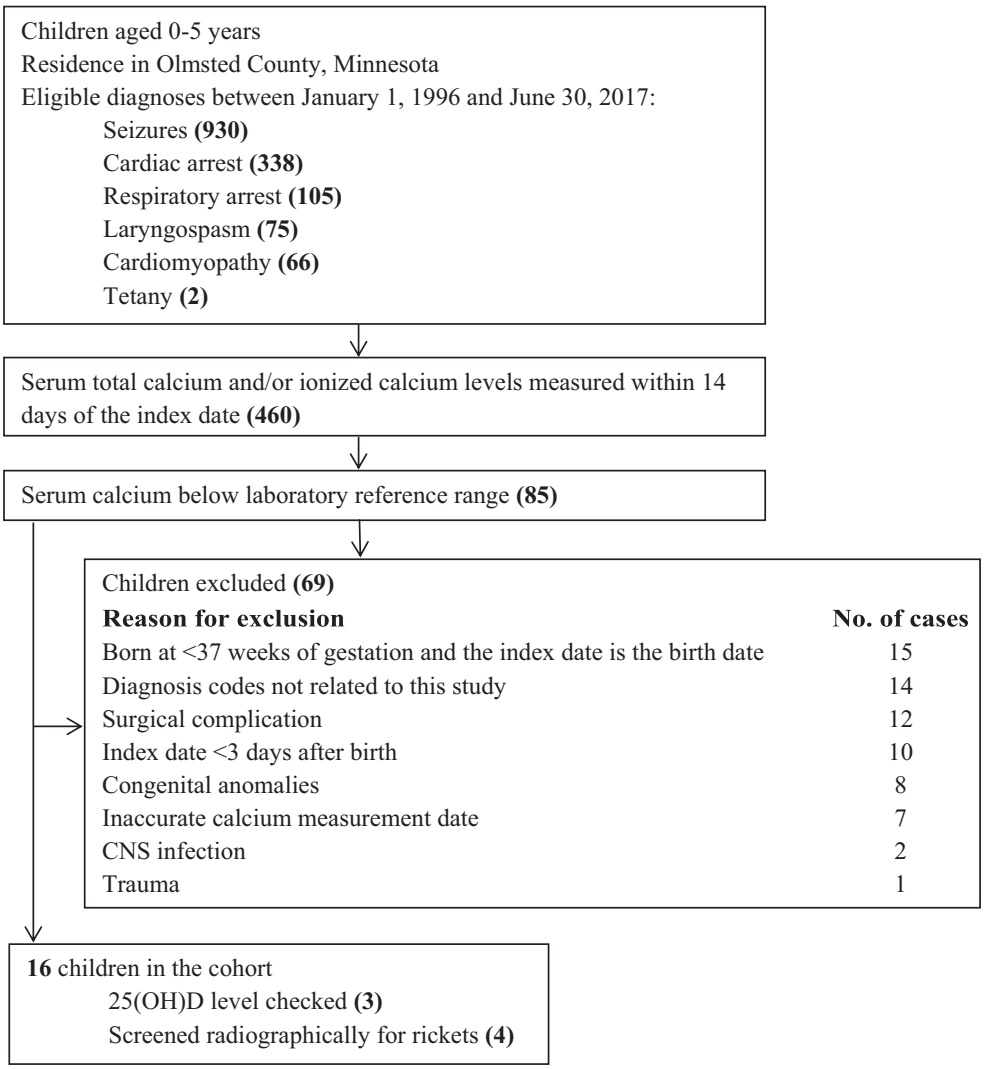

Figure 1. Study flow chart showing inclusion and exclusion criteria. Numbers of patients are shown in parentheses. *CNS*, central nervous system.

complications (0.2%). Seizures were the most frequent life-threatening complication (61%), followed by cardiac arrest (22%). Of the 105 patients who experienced respiratory arrest, 21 (20%) had hypocalcemia, the highest proportion of any complication (**Figure 2**; **Table II**).

From the group of 85 patients who had hypocalcemia, we excluded 69 patients who were judged to more likely have had causes other than hypocalcemia trigger the complication (**Figure 1**), leaving 16 patients in our study group (**Table III**). Children were excluded most commonly because they were born at <37 weeks of gestation, and the date of their complication was their birth date. Ten of the 16 patients (63%) were males, and 7 (44%) were black. The mean (±SD) age at the index date was 13.5 ± 13.6 months; the median age was 10.3 months. The mean age at the time of complication was 8.0 months of age in white children and 17.5 months of age in black children. The mean total calcium was 7.52 ± 1.11 mg/dL and mean ionized calcium was 2.8 ± 0.68 mg/dL. The median alkaline phosphatase was 452 U/L (range, 134-2122 U/L). The mean length/height percentile was 22.8 ± 24.5 and mean weight percentile was 34.7 ± 34.8.

Among the 4 children with radiographs, 2 were indicated to rule out child abuse. Among these, 1 child had no fractures identified and in the other the presence of fractures could not be determined. There were no signs of osteopenia. The other 2 radiographs were to evaluate for possible rickets, which was found in both cases. Owing to a lack of additional radiographs, we do not know whether other infants and children had radiographic evidence of osteopenia or rickets.

Ten of the 16 children (63%) experienced a hypocalcemic complication between December and April, months with limited sun exposure in Minnesota. Five of the 16 children (31%) experienced a hypocalcemic complication between 1996 and 2000, 5 (31%) between 2001 and 2005, 2 (13%) between 2006 and 2010, 3 (19%) between 2011 and 2015, and 1 (6%) after 2015.

Table II. Distribution of complications in 1305 children

Cardiac arrest	Cardiomyopathy	Laryngospasm	Respiratory arrest	Seizure	Tetany	No. of children overall	No. with calcium checked	No. with low calcium
					X	1	0	0
				X		770	221	23
			X			60	31	13
			X		X	1	1	1
			X	X		12	10	3
		X				66	1	0
		X		X		2	1	0
		X	X			2	0	0
	X					42	7	0
	X			X		11	8	0
X						169	82	29
X				X		123	71	8
X			X			24	12	2
X			X	X		4	4	1
X		X				3	2	1
X		X		X		2	1	0
X	X					6	4	0
X	X			X		5	3	3
X	X		X	X		2	1	1
					Total	1305	460	85

Of the 16 patients in the study group, only 3 (19%) had serum 25(OH)D measured. Two (patients 7 and 8 in Table III) had 25(OH)D values of ≤6 ng/mL (15 nmol/L; reference range, 20-50 ng/mL [50-125 nmol/L]), and both received treatment with calcitriol. Patient 7 was 3-6 months old when hospitalized during winter for a respiratory illness. Within 2 days of admission, the infant developed tetany and respiratory arrest from hypocalcemic laryngospasm. This infant was exclusively breastfed and had no record of vitamin D supplementation before hospitalization. Patient 8 presented in winter at 6-9 months of age with cardiac arrest, respiratory failure, and tonic seizures. Three weeks earlier, the infant had experienced 2 apneic spells accompanied by arm and leg stiffening and eye fixation during an upper respiratory tract infection. The infant's diet included breast milk and baby foods, but no vitamin D supplementation. The infant was underweight.

Although all 16 patients had hypocalcemia, 3 were treated with oral or intravenous calcium chloride or calcium carbonate including patients 7 and 8. Only patients 7 and 8 had

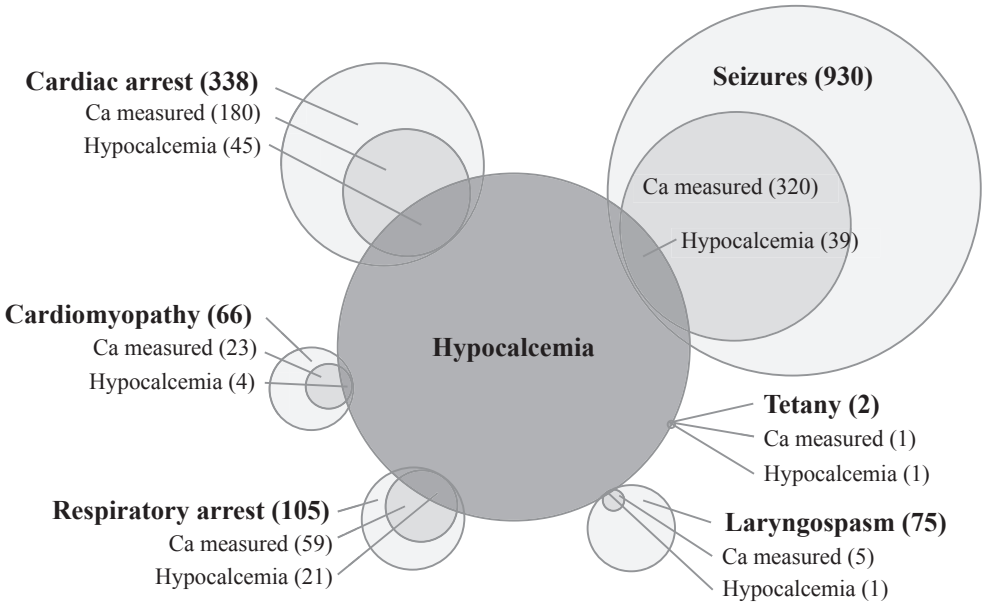

Figure 2. Relative proportions of 1305 children with complications who had calcium (Ca) measured and who had hypocalcemia. Numbers of patients are shown in parentheses and the relative sizes of the circles are approximate. One hundred ninety-seven children (15.1%) had more than one complication, resulting in the sums of categories exceeding the total number of patients.

Table III. Characteristics of 16 children with hypocalcemic complications

Patients	Age at index date, months	Year of complication (before or after 1/1/2000)	Diagnoses	Total calcium*	Ionized calcium†	25(OH)D‡	Alkaline phosphatase§	Rickets present on radiograph	Length/height percentile	Weight percentile	Diet during infancy before index date
1	0-3	After	Seizures		2.0				0-5	0-5	Breast milk and formula
2	0-3	After	Seizures	8.0					75-80	60-65	Breast milk
3	0-3	After	Seizures	6.9					0-5	15-20	Breast milk and formula
4	0-3	After	Seizures, cardiac arrest		1.61		134		0-5	0-5	Breast milk and formula
5	0-3	Before	Cardiac arrest		3.48					0-5	Breast milk
6	3-6	After	Seizures, cardiomyopathy, cardiac arrest		3.3		418	No	0-5	10-15	Breast milk and formula
7	3-6	After	Respiratory arrest, tetany	6.8	2.0	4.0	2122	Yes	30-35	50-55	Breast milk
8	6-9	After	Seizures, cardiac arrest, respiratory arrest	4.8	2.7	6.0	723	Yes	30-35	0-5	Breast milk
9	12-15	After	Cardiac arrest, respiratory arrest		2.6					80-85	Breast milk
10	12-15	After	cardiac arrest		3.4			No		75-80	Breast milk and formula
11	15-18	After	Seizures	7.8	3.69	51.0			55-60	60-65	Formula
12	18-21	After	Seizures	8.4			425		10-15	10-15	Formula
13	24-27	Before	Seizures	8.7			452				
14	24-27	After	Seizures	8.4					10-15	0-5	Breast milk and formula
15	27-30	After	Seizures	8.3						95-100	Breast milk and formula
16	48-51	After	Seizures, cardiac arrest	7.1	3.0		502				Breast milk and formula

Blank cells indicate that data were not available.
*Reference range, 8.8-10.8 mg/dL.
†Reference range, 3.7-5.5 mg/dL.
‡Reference range, 20-50 ng/mL.
§Reference range, 83-248 U/L at 0-14 days; 122-469 U/L at 15 days to <1 year; and 142-335 U/L at 1-10 years of age.

radiographic assessment for rickets, and both had rickets. Patients 6 and 10 had radiographs for other reasons, and no evidence of rickets was found. Four patients died within 9 days of the index date, but the 2 patients with confirmed rickets both survived. The 2 infants with rickets had the lowest serum total calcium measurements among the cohort and had elevated alkaline phosphatase values, consistent with rickets. Three others had elevated alkaline phosphatase values but did not have 25(OH)D measured or radiographs to exclude vitamin D deficiency or rickets.

Five children were exclusively breastfed, and 2 of these children had documentation in their medical records recommending vitamin D supplementation. Forty percent of children were less than the 5th percentile for length/height and 36% (of 14 children) were less than the 5th percentile for weight, which are considered short stature and underweight, respectively.

Of children aged 0-5 years in Olmsted County during the study period, the incidence of hypocalcemia and a potentially life-threatening complication was 6.1 per 100 000 person-years (95% CI, 3.5-10.0). The race-specific incidence of hypocalcemia and a potentially life-threatening complication for those 0-4 years of age was 3.1 (95% CI, 1.1-8.8), 39.7 (95% CI, 18.9-83.3), and 7.2 (95% CI, 1.5-34.6) per 100 000 person-years for white, black, and other race, respectively. Blacks had a significantly higher incidence compared with whites or others ($P < .001$ and $P = .033$, respectively). There was no significant difference between whites and other race ($P = .29$).

Discussion

For the majority of children with life-threatening complications of hypocalcemia, it is unknown whether vitamin D deficiency contributed to their hypocalcemia, because serum 25(OH)D was never measured. Despite this, we confirmed 2 cases of hypocalcemic cardiac and respiratory arrest owing to severe vitamin D deficiency, which was associated with rickets. Their 25(OH)D values of ≤6 ng/mL placed them profoundly below the lower end of the recommended minimum of 20 ng/mL. Both were breastfed and experienced hypocalcemic complications during the winter months. The details of one of these cases have been published previously.[27]

Although hypocalcemia should usually prompt measurement of 25(OH)D levels, vitamin D status was not assessed in the majority of children in our study. However, many children with hypocalcemic complications possessed risk factors for vitamin D deficiency. Thus, it is possible that vitamin D deficiency contributed to hypocalcemia in additional children in our cohort. A majority of infants in our study were exclusively breastfed. Human milk is a poor source of vitamin D, and breastfeeding without supplementation is an independent predictor of vitamin D deficiency in infants.[1,28,29] Maternal vitamin D deficiency was the main etiologic factor for complications of neonatal hypocalcemia in some parts of the world.[30] According to the American

Academy of Pediatrics, all breastfed and partially breastfed infants should receive 400 IU/day of supplemental vitamin D starting in the first few days of life.[31] The National Academy of Medicine (formerly the Institute of Medicine) and a global consensus report both recommend an adequate intake of 400 IU/day for all infants zero to 12 months of age, regardless of their mode of feeding.[6,32] Additionally, an Endocrine Society clinical practice guideline suggests lactating women need 1400-1500 IU/day, some of which may come from a maternal supplement to meet their child's vitamin D needs if their child receives routine supplementation, or 4000-6000 IU/day if their infant is not receiving his or her own vitamin D supplement.[4] Although less than one-half of the children who were exclusively breastfed had documentation in their medical records recommending vitamin D supplementation, it is possible that other individuals were, in fact, advised to take supplemental vitamin D. Regardless, the hypocalcemia in all of these children suggest that health care providers should not only recommend vitamin D supplementation to those who are breastfed but should also follow-up with parents to ensure supplementation is being administered appropriately.

Forty-four percent of children in our study were black or African American, compared with approximately 6.5% of children <5 years of age in Olmsted County. This supports evidence that 25(OH)D deficiency is more prevalent among dark-skinned individuals than light-skinned individuals[33] and that 25(OH)D deficiency may have a greater role in causing hypocalcemia in black compared with white children. White children presented, on average, at a younger age than black children, suggesting potentially different causes of hypocalcemia according to race. Whatever the cause, this finding highlights the importance of ensuring that all children, regardless of race or degree of skin pigmentation, receive appropriate vitamin D supplements and/or fortification.

The greater than expected proportion of children with short stature or underweight prompt one to consider whether factors like inadequate nutrition, intestinal malabsorption, or confounding health problems influenced the growth and vitamin D status in the group with hypocalcemic complications.

Three-quarters of the children in our study had life-threatening complications of hypocalcemia at <2 years of age. In another study, vitamin D deficient-children aged 0-16 years who presented with symptoms of hypocalcemia were exclusively <3 or >10 years of age, ages associated with relatively increased growth velocity.[34] Our data support the assertion that, during periods of rapid growth, there is an increased requirement for calcium, which can lead to manifestations of hypocalcemia in patients with vitamin D deficiency.

The risk of vitamin D deficiency in temperate climates is greatest during winter and spring months.[35-37] Given Olmsted County is located at 44°N latitude, individuals cannot synthesize enough cutaneous vitamin D during winter to meet their requirements.[3] In our study, the majority of complications of hypocalcemia occurred during winter and spring, supporting the contention that seasonality is an important contributor to vitamin D deficiency.

A major strength of our study is that it provides population-based data regarding the rate of hypocalcemic complications over a span of >20 years. There are also a number of limitations to this study. Our study group was small, which limits the precision of our incidence estimate and our ability to test for patterns in time of year, diet, and trends over time. Additionally, we investigated patients who had hypocalcemic measurements taken within 14 days of their index date. We likely missed additional children with hypocalcemia who did not have their serum calcium or 25(OH)D measured, and our incidence rate likely underestimates the true burden of vitamin D deficiency. Excluding neonates also potentially underestimates the impact of vitamin D deficiency, because maternal vitamin D deficiency can cause neonatal vitamin D deficiency, resulting in hypocalcemic manifestations. Although it is possible that children who never presented for medical care were not included in the incidence denominator, we speculate that this number is likely small, because children in this age group routinely present for health care maintenance visits. Because we recorded 25(OH)D and alkaline phosphatase measurements within 6 months of the index date, some values may reflect a different season than the time of presentation, thereby limiting their interpretability. Although our study centered on hypocalcemia as a cause of potentially life-threatening complications, it is possible that in some cases the complication could have caused hypocalcemia. Among the patients we excluded for prematurity, complications during the neonatal period, and hypocalcemia not occurring within 14 days of a complication, vitamin D deficiency could have been the cause of their complication. Last, we had a relatively low proportion of blacks in our population compared with the US average. Because blacks are at greater risk for vitamin D deficiency and complications of hypocalcemia, the incidence of hypocalcemic complications may be even greater in the greater US population.

These results suggest that vitamin D deficiency is an often underinvestigated and, therefore, potentially underrecognized cause of severe hypocalcemic complications in young children. Our data show that, if clinicians do not check 25(OH)D status in children with hypocalcemia, vitamin D deficiency will not be identified. To decrease the risk of hypocalcemia and vitamin D deficiency, we encourage the education of parents about risk factors for vitamin D deficiency and its potential dangers, as well as the benefits of appropriate sunlight exposure, vitamin D-rich diets, and when indicated, vitamin D supplementation, for their children. Among children in our study with complications likely caused by hypocalcemia, measurement of 25(OH)D was uncommon. We recommend that clinicians measure serum calcium, 25(OH)D, and alkaline phosphatase in children with known complications of hypocalcemia to identify and treat life-threatening vitamin D deficiency swiftly and appropriately. ■

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Data Statement

Data sharing statement available at www.jpeds.com.

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Table I. ***International Classification of Diseases 9th and 10th edition*** **codes**

Codes	Description	Type
I46.2	Cardiac arrest due to underlying cardiac condition	I10
I46.8	Cardiac arrest due to other underlying condition	I10
I46.9	Cardiac arrest, cause unspecified	I10
Z86.74	Personal history of sudden cardiac arrest	I10
P29.81	Cardiac arrest of newborn	I10
I97.120	Postprocedural cardiac arrest following cardiac surgery	I10
I97.121	Postprocedural cardiac arrest following other surgery	I10
I97.710	Intraoperative cardiac arrest during cardiac surgery	I10
I97.711	Intraoperative cardiac arrest during other surgery	I10
O03.36	Cardiac arrest following incomplete spontaneous abortion	I10
O03.86	Cardiac arrest following complete or unspecified spontaneous abortion	I10
O04.86	Cardiac arrest following (induced) termination of pregnancy	I10
O07.36	Cardiac arrest following failed attempted termination of pregnancy	I10
O08.81	Cardiac arrest following an ectopic and molar pregnancy	I10
O29.111	Cardiac arrest due to anesthesia during pregnancy, first trimester	I10
O29.112	Cardiac arrest due to anesthesia during pregnancy, second trimester	I10
O29.113	Cardiac arrest due to anesthesia during pregnancy, third trimester	I10
O29.119	Cardiac arrest due to anesthesia during pregnancy, unspecified trimester	I10
427.5	Cardiac arrest	I9
V12.53	Per hx sudden card arrest	I9
997.1	Cardiac complications, not elsewhere classified (includes cardiac arrest as a complication of surgical procedure)	I9
779.85	Cardiac arrest of newborn	I9
V12.59	Per hx sudden card arrest	I9
779.89	Cardiac arrest of newborn	I9
R09.2	Respiratory arrest	I10
P28.5	Respiratory failure of newborn	I10
P28.81	Respiratory arrest of newborn	I10
P28.89	Other specified respiratory conditions of newborn	I10
P28.9	Respiratory condition of newborn, unspecified	I10
770.8	Other newborn respiratory problems	I9
770.81	Primary apnea of newborn	I9
770.82	Other apnea of newborn	I9
770.83	Cyanotic attacks of newborn	I9
770.84	Respiratory failure of newborn	I9
770.87	Respiratory arrest of newborn	I9
770.88	Hypoxemia of newborn	I9
770.89	Other respiratory problems after birth	I9
799.1	Respiratory arrest	I9
770.8	Other newborn respiratory problems	I9
770.89	Other respiratory problems after birth	I9
768.9	Hypoxemia of newborn	I9
A36.81	Diphtheritic cardiomyopathy	I10
B33.24	Viral cardiomyopathy	I10
E85.4	Organ-limited amyloidosis	I10
I25.5	Ischemic cardiomyopathy	I10
I42.0	Dilated cardiomyopathy	I10
I42.1	Obstructive hypertrophic cardiomyopathy	I10
I42.2	Other hypertrophic cardiomyopathy	I10
I42.3	Endomyocardial (eosinophilic) disease	I10
I42.4	Endocardial fibroelastosis	I10
I42.5	Other restrictive cardiomyopathy	I10
I42.6	Alcoholic cardiomyopathy	I10
I42.7	Cardiomyopathy due to drug and external agent	I10
I42.8	Other cardiomyopathies	I10
I42.9	Cardiomyopathy, unspecified	I10
I43	Cardiomyopathy in diseases classified elsewhere	I10
O90.3	Peripartum cardiomyopathy	I10
425	Cardiomyopathy	I9
425.0	Endomyocardial fibrosis	I9
425.1	Hypertrophic (obstructive) cardiomyopathy	I9
425.11	Hypertrophic obstructive cardiomyopathy	I9
425.18	Other hypertrophic cardiomyopathy	I9
425.2	Obscure cardiomyopathy of Africa	I9
425.3	Endocardial fibroelastosis	I9
425.4	Other primary cardiomyopathies	I9
425.5	Alcoholic cardiomyopathy	I9
425.7	Nutritional and metabolic cardiomyopathy	I9
425.8	Cardiomyopathy in other diseases classified elsewhere	I9
425.9	Secondary cardiomyopathy, unspecified	I9
674.5	Peripartum cardiomyopathy	I9

(*continued*)

Table I. Continued

Codes	Description	Type
674.50	Peripartum cardiomyopathy, unspec as to episode of care or not applicable	I9
674.51	Peripartum cardiomyopathy, delivered, w or wo mention of antepartum condition	I9
674.52	Peripartum cardiomyopathy, delivered, with mention of postpartum condition	I9
674.53	Peripartum cardiomyopathy, antepartum condition or complication	I9
674.54	Peripartum cardiomyopathy, postpartum condition or complication	I9
277.39	Other amyloidosis (includes cardiomyopathy)	I9
425.1	Hypertrophic obstructive cardiomyopathy	I9
425.4	Other hypertrophic cardiomyopathy	I9
674.8	Peripartum cardiomyopathy, unspec as to episode of care or not applicable	I9
674.82	Peripartum cardiomyopathy, unspec as to episode of care or not applicable	I9
674.84	Peripartum cardiomyopathy, unspec as to episode of care or not applicable	I9
277.3	Other amyloidosis (includes cardiomyopathy)	I9
J38.5	Laryngeal spasm	I10
478.75	Laryngeal spasm	I9
G40.001	Localization-related (focal) (partial) idiopathic epilepsy and epileptic syndromes with seizures of localized onset, not intractable, with status epilepticus	I10
G40.009	Localization-related (focal) (partial) idiopathic epilepsy and epileptic syndromes with seizures of localized onset, not intractable, without status epilepticus	I10
G40.011	Localization-related (focal) (partial) idiopathic epilepsy and epileptic syndromes with seizures of localized onset, intractable, with status epilepticus	I10
G40.019	Localization-related (focal) (partial) idiopathic epilepsy and epileptic syndromes with seizures of localized onset, intractable, without status epilepticus	I10
G40.101	Localization-related (focal) (partial) symptomatic epilepsy and epileptic syndromes with simple partial seizures, not intractable, with status epilepticus	I10
G40.109	Localization-related (focal) (partial) symptomatic epilepsy and epileptic syndromes with simple partial seizures, not intractable, without status epilepticus	I10
G40.111	Localization-related (focal) (partial) symptomatic epilepsy and epileptic syndromes with simple partial seizures, intractable, with status epilepticus	I10
G40.119	Localization-related (focal) (partial) symptomatic epilepsy and epileptic syndromes with simple partial seizures, intractable, without status epilepticus	I10
G40.201	Localization-related (focal) (partial) symptomatic epilepsy and epileptic syndromes with complex partial seizures, not intractable, with status epilepticus	I10
G40.209	Localization-related (focal) (partial) symptomatic epilepsy and epileptic syndromes with complex partial seizures, not intractable, without status epilepticus	I10
G40.211	Localization-related (focal) (partial) symptomatic epilepsy and epileptic syndromes with complex partial seizures, intractable, with status epilepticus	I10
G40.219	Localization-related (focal) (partial) symptomatic epilepsy and epileptic syndromes with complex partial seizures, intractable, without status epilepticus	I10
G40.301	Generalized idiopathic epilepsy and epileptic syndromes, not intractable, with status epilepticus	I10
G40.309	Generalized idiopathic epilepsy and epileptic syndromes, not intractable, without status epilepticus	I10
G40.311	Generalized idiopathic epilepsy and epileptic syndromes, intractable, with status epilepticus	I10
G40.319	Generalized idiopathic epilepsy and epileptic syndromes, intractable, without status epilepticus	I10
G40.A01	Absence epileptic syndrome, not intractable, with status epilepticus	I10
G40.A09	Absence epileptic syndrome, not intractable, without status epilepticus	I10
G40.A11	Absence epileptic syndrome, intractable, with status epilepticus	I10
G40.A19	Absence epileptic syndrome, intractable, without status epilepticus	I10
G40.B01	Juvenile myoclonic epilepsy, not intractable, with status epilepticus	I10
G40.B09	Juvenile myoclonic epilepsy, not intractable, without status epilepticus	I10
G40.B11	Juvenile myoclonic epilepsy, intractable, with status epilepticus	I10
G40.B19	Juvenile myoclonic epilepsy, intractable, without status epilepticus	I10
G40.401	Other generalized epilepsy and epileptic syndromes, not intractable, with status epilepticus	I10
G40.409	Other generalized epilepsy and epileptic syndromes, not intractable, without status epilepticus	I10
G40.411	Other generalized epilepsy and epileptic syndromes, intractable, with status epilepticus	I10
G40.419	Other generalized epilepsy and epileptic syndromes, intractable, without status epilepticus	I10
G40.501	Epileptic seizures related to external causes, not intractable, with status epilepticus	I10
G40.509	Epileptic seizures related to external causes, not intractable, without status epilepticus	I10
G40.801	Other epilepsy, not intractable, with status epilepticus	I10
G40.802	Other epilepsy, not intractable, without status epilepticus	I10
G40.803	Other epilepsy, intractable, with status epilepticus	I10
G40.804	Other epilepsy, intractable, without status epilepticus	I10
G40.811	Lennox-Gastaut syndrome, not intractable, with status epilepticus	I10
G40.812	Lennox-Gastaut syndrome, not intractable, without status epilepticus	I10
G40.813	Lennox-Gastaut syndrome, intractable, with status epilepticus	I10
G40.814	Lennox-Gastaut syndrome, intractable, without status epilepticus	I10
G40.821	Epileptic spasms, not intractable, with status epilepticus	I10
G40.822	Epileptic spasms, not intractable, without status epilepticus	I10
G40.823	Epileptic spasms, intractable, with status epilepticus	I10
G40.824	Epileptic spasms, intractable, without status epilepticus	I10
G40.89	Other seizures	I10
G40.901	Epilepsy, unspecified, not intractable, with status epilepticus	I10

(*continued*)

Table I. Continued

Codes	Description	Type
G40.909	Epilepsy, unspecified, not intractable, without status epilepticus	I10
G40.911	Epilepsy, unspecified, intractable, with status epilepticus	I10
G40.919	Epilepsy, unspecified, intractable, without status epilepticus	I10
R56.00	Simple febrile convulsions	I10
R56.01	Complex febrile convulsions	I10
R56.1	Post traumatic seizures	I10
R56.9	Unspecified convulsions	I10
P90	Convulsions of newborn	I10
F44.5	Conversion disorder with seizures or convulsions	I10
123.1	Cysticercosis	I9
291.0	Alcohol withdrawal delirium	I9
300.11	Conversion disorder	I9
333.2	Myoclonus	I9
344.8	Other specified paralytic syndromes	I9
344.81	Other specified paralytic syndromes, locked-in state	I9
344.89	Other specified paralytic syndromes, other specified paralytic syndrome	I9
345	Epilepsy	I9
345.0	Generalized nonconvulsive epilepsy	I9
345.00	Generalized nonconvulsive epilepsy-without mention of intractable epilepsy	I9
345.01	Generalized nonconvulsive epilepsy-with intractable epilepsy	I9
345.1	Generalized convulsive epilepsy	I9
345.10	Generalized convulsive epilepsy-without mention of intractable epilepsy	I9
345.11	Generalized convulsive epilepsy-with intractable epilepsy	I9
345.2	Petit mal status, epileptic	I9
345.3	Grand mal status, epileptic	I9
345.4	Partial epilepsy, with impairment of consciousness	I9
345.40	Localization-related (focal) (partial) epilepsy and epileptic syndromes with complex partial seizures, without mention of intractable epilepsy	I9
345.41	Localization-related (focal) (partial) epilepsy and epileptic syndromes with complex partial seizures, with intractable epilepsy	I9
345.5	Partial epilepsy, without mention of impairment of consciousness	I9
345.50	Localization-related (focal) (partial) epilepsy and epileptic syndromes with simple partial seizures, without mention of intractable epilepsy	I9
345.51	Localization-related (focal) (partial) epilepsy and epileptic syndromes with simple partial seizures, with intractable epilepsy	I9
345.6	Infantile spasms	I9
345.60	Infantile spasms-without mention of intractable epilepsy	I9
345.61	Infantile spasms-with intractable epilepsy	I9
345.7	Epilepsia partialis continua	I9
345.70	Epilepsia partialis continua-without mention of intractable epilepsy	I9
345.71	Epilepsia partialis continua-with intractable epilepsy	I9
345.8	Other forms of epilepsy	I9
345.80	Other forms of epilepsy and recurrent seizures, without mention of intractable epilepsy	I9
345.81	Other forms of epilepsy and recurrent seizures, with intractable epilepsy	I9
345.9	Epilepsy, unspecified	I9
345.90	Epilepsy, unspecified-without mention of intractable epilepsy	I9
345.91	Epilepsy, unspecified-with intractable epilepsy	I9
780.3	Convulsions	I9
780.31	Febrile convulsions	I9
780.32	Complex febrile convulsions	I9
780.33	Post traumatic seizures	I9
780.39	Other convulsions	I9
779.0	Convulsions in newborn	I9
344.8	Other specified paralytic syndromes, other specified paralytic syndrome	I9
345.0	Generalized nonconvulsive epilepsy-without mention of intractable epilepsy	I9
345.1	Generalized convulsive epilepsy-without mention of intractable epilepsy	I9
345.4	Localization-related (focal) (partial) epilepsy and epileptic syndromes with complex partial seizures	I9
345.5	Localization-related (focal) (partial) epilepsy and epileptic syndromes with simple partial seizures	I9
345.7	Epilepsia partialis continua-without mention of intractable epilepsy	I9
345.8	Other forms of epilepsy and recurrent seizures, without mention of intractable epilepsy	I9
345.9	Epilepsy, unspecified-without mention of intractable epilepsy	I9
780.3	Febrile convulsions	I9
780.39	Complex febrile convulsions	I9
780.3	Other convulsions	I9
P71.3	Neonatal tetany without calcium or magnesium deficiency	I10
R29.0	Tetany	I10
781.7	Tetany	I9
E55.0	Rickets, active	I10
E55.9	Vitamin d deficiency, unspecified	I10
E83.51	Hypocalcemia	I10
E58	Dietary calcium deficiency	I10

(*continued*)

Table I. Continued

Codes	Description	Type
P71.0	Cow's milk hypocalcemia in newborn	I10
P71.1	Other neonatal hypocalcemia	I10
P71.9	Transitory neonatal disorder of calcium and magnesium metabolism, unspecified	I10
268	Vitamin d deficiency	I9
268.0	Rickets, active	I9
269.1	Deficiency of other vitamins	I9
268.2	Osteomalacia, unspecified	I9
268.9	Unspecified vitamin d deficiency	I9
275.4	Disorders of calcium metabolism	I9
275.40	Unspecified disorder of calcium metabolism	I9
275.41	Hypocalcemia	I9
275.5	Hungry bone syndrome	I9
775.4	Hypocalcemia and hypomagnesemia of newborn	I9