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Reversible Lactic Acidosis in a Newborn With Thiamine Transporter-2 Deficiency

Belén Pérez-Dueñas, Mercedes Serrano, Mónica Rebollo, Jordi Muchart, Eva Gargallo, Celine Dupuits and Rafael Artuch

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Reversible Lactic Acidosis in a Newborn With Thiamine Transporter-2 Deficiency

abstract

Thiamine transporter-2 deficiency is a recessive disease caused by mutations in the *SLC19A3* gene. Patients manifest acute episodes of encephalopathy; symmetric lesions in the cortex, basal ganglia, thalami or periaqueductal gray matter, and a dramatic response to biotin or thiamine. We report a 30-day-old patient with mutations in the *SLC19A3* gene who presented with acute encephalopathy and increased level of lactate in the blood (8.6 mmol/L) and cerebrospinal fluid (7.12 mmol/L), a high excretion of α-ketoglutarate in the urine, and increased concentrations of the branched-chain amino acids leucine and isoleucine in the plasma. MRI detected bilateral and symmetric cortico-subcortical lesions involving the perirolandic area, bilateral putamina, and medial thalami. Some lesions showed low apparent diffusion coefficient values suggesting an acute evolution; others had high values likely to be subacute or chronic, most likely related to the perinatal period. After treatment with thiamine and biotin, irritability and opisthotonus disappeared, and the patient recovered consciousness. Biochemical disturbances also disappeared within 48 hours. After discontinuing biotin, the patient remained stable for 6 months on thiamine supplementation (20 mg/kg/day). The examination revealed subtle signs of neurologic sequelae, and MRI showed necrotic changes and volume loss in some affected areas. Our observations suggest that patients with thiamine transporter 2 deficiency may be vulnerable to metabolic decompensation during the perinatal period, when energy demands are high. Thiamine defects should be excluded in newborns and infants with lactic acidosis because prognosis largely depends on the time from diagnosis to thiamine supplementation. *Pediatrics* 2013;131:e1670–e1675

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KEY WORDS

biotin, Leigh syndrome lactic acidosis, mitochondrial encephalopathy, perinatal brain injury, *SLC19A3* gene, thiamine, thiamine transporter-2

ABBREVIATIONS

ADC—apparent diffusion coefficient
hTHTR1—thiamine transporter 1
hTHTR2—thiamine transporter 2
RV—reference values

Dr Pérez-Dueñas conceptualized and designed the study, drafted the initial manuscript, and approved the final manuscript as submitted; Dr Serrano reviewed the manuscript, revised the manuscript, and approved the final manuscript as submitted; Dr Rebollo contributed to the analysis and interpretation of neuroradiologic studies and to the review and critique of the manuscript; Dr Muchart contributed to the analysis and interpretation of neuroradiologic studies and to the review and critique of the manuscript; Dr Gargallo contributed to the analysis and interpretation of clinical features and to the review and critique of the manuscript; Ms Dupuis contributed to the analysis and interpretation of molecular studies and to the review and critique of the manuscript; and Dr Artuch contributed to the analysis and interpretation of biochemical studies and to the critical revision of the manuscript.

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Thiamine transporter 2 (hTHTR2) deficiency is an inherited autosomal recessive disease due to mutations in the *SLC19A3* gene.[1] Three clinical variants have been related to the defect: biotin-responsive basal ganglia disease,[2–4] Wernicke-like encephalopathy,[5] and atypical infantile spasms with progressive cerebral atrophy and basal ganglia lesions.[6] Despite the great variation among these phenotypes, they share relevant clinical features: (1) most affected children present with acute and recurrent episodes of encephalopathy that are sometimes triggered by febrile illnesses, vaccination, or trauma; (2) brain lesions are symmetrically distributed in the cerebral cortex, basal ganglia, thalami, or periaqueductal gray matter; and (3) children show a dramatic clinical improvement when biotin or thiamine is administered early in relation to the onset of symptoms.

Our aim was to report a 30-day-old infant with acute encephalopathy and lactic acidosis due to hTHTR2 deficiency. Thiamine and biotin supplementation resulted in an excellent clinical and biochemical outcome.

CASE REPORT

This 1-month-old male infant was referred to our center because of a 3-day history of poor feeding, vomiting, and irritability. He was the first son of healthy consanguineous parents from Morocco. After a monitored and uneventful pregnancy, the patient was delivered at 38 weeks by emergent cesarean delivery due to suspicion of fetal distress. His Apgar scores were 8/9; his birth weight was 2530 g (5th percentile), and his head circumference was 33 cm (20th percentile). The umbilical cord blood acid-base status was normal.

The examination at 1 month of life showed a nondysmorphic child with normal vital signs; his weight was 3.570 g (6th percentile), and his head circumference was 36.5 cm (20th percentile). There were no clinical or biological signs of infection. He appeared lethargic and had intermittent opisthotonus, jitteriness in the upper limbs, hyperreflexia and clonus in the 4 limbs, decreased palmar and plantar grasp reflexes, and an exaggerated Moro reflex. A biochemical analysis showed mild metabolic acidosis (venous pH: 7.30, pCO_2: 37 mm Hg, base excess: –6.4) and high lactate levels in blood (8.6 mmol/L; reference values [RV]: 0.7–2.4) and cerebrospinal fluid (7.1 mmol/L; RV: 1.1–2.2). Viral and bacterial tests were negative.

Plasma amino acids showed increased concentrations of alanine (637 μmol/L; RV: 167–439 μmol/L), leucine (182 μmol/L; RV: 79–150 μmol/L), isoleucine (97 μmol/L; RV: 40–90 μmol/L) and alloisoleucine (3.1 μmol/L; RV: 0; Fig 1); urine organic acid analysis disclosed a high excretion of lactate (3537 mmol/mol creatinine; RV: $<$270 mmol/mol creatinine) and α-ketoglutarate (1157 mmol/mol creatinine; RV: 20–340 mmol/mol creatinine).

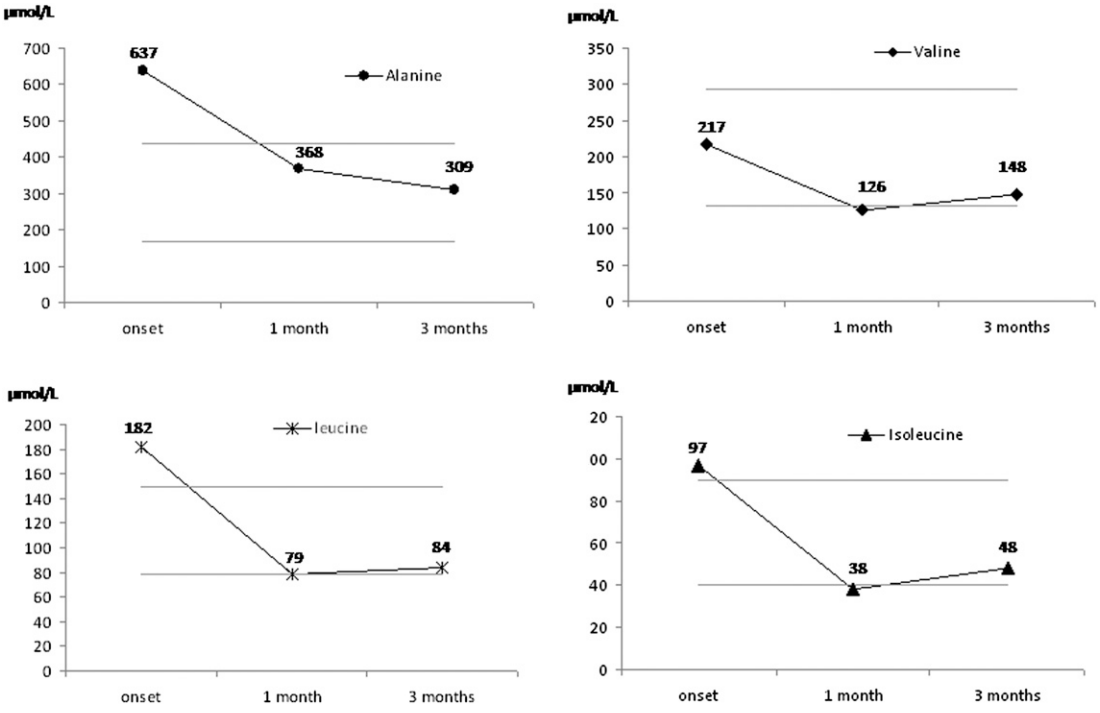

FIGURE 1

These illustrations show the plasma concentrations of alanine and the branched-chain amino acids valine, leucine, and isoleucine in our patient at onset (first point) and on follow-up with thiamine administration (last 2 points). Leucine, isoleucine and alanine normalized after thiamine administration.

Biotinidase activity was within normal limits. A cranial ultrasound detected basal ganglia hyperechogenicity combined with patchy hyperechoic cortical/subcortical lesions, resembling a hypoxic-ischemic encephalopathy pattern (images not shown). MRI 24 hours after hospitalization showed bilateral and symmetric cortico-subcortical lesions involving the perirolandic area, bilateral putamina, and medial thalami. Some brain lesions showed low apparent diffusion coefficient (ADC) values, suggesting an acute process. Others had high ADC values that were likely to be due to subacute or chronic processes (Fig 2A–E). Magnetic resonance spectroscopy demonstrated a mild lactate peak. A video EEG recorded occasional bilateral parietal spikes, but clinical seizures were not evident in the patient. Background trace was within normal parameters. The echocardiogram was normal.

OUTCOME AND DIAGNOSIS

With the suspicion of mitochondrial encephalopathy based on analytical findings and MRI features, a combination of thiamine (100 mg/day), biotin (10 mg/day), and carnitine (300 mg/day) was started. There was a dramatic clinical and biochemical improvement in the hours after initiation of therapy: irritability and feeding difficulties ceased within 24 hours of treatment; later, opisthotonus disappeared, and the patient recovered consciousness. After 48 hours, blood lactate levels decreased from 8.6 mmol/L to 2.6 mmol/L, the acid-base status normalized, and the levels of urine organic acids normalized (lactate 33 mmol/mol creatinine and α-ketoglutarate 110 mmol/mol creatinine). One month later, plasma amino acid values were normal (alanine 309 μmol/L; leucine 84 μmol/L; isoleucine 48 μmol/L; alloisoleucine undetectable; Fig 1). The patient was discharged after 6 days of hospitalization with a normal physical examination, except for a mild increase in muscle tone in the lower limbs.

The patient's excellent response to the combination of thiamine and biotin led to our suspicion that he had an hTHTR2 deficiency. Molecular analysis of the *SLC19A3* gene indicated that the child was homozygous for the previously reported pathogenic mutation p.Gly23Val.[1] The parents were both heterozygous for this amino acid substitution.

After confirming the diagnosis through molecular studies, biotin and carnitine were discontinued, and thiamine was maintained at 20 mg/kg/day. At age 6 months, the child remained stable. On examination, he presented with normal ocular pursuit and social interaction. Weight, height, and head circumference were in the 25th percentile. The patient's axial tone was normal, he had good head control, and he could roll over. Muscle tone was mildly increased in upper limbs; there was some asymmetry of fine motor skills with impaired palmar grasp and thumb adduction of the right hand.

Follow-up MRI at 6 months showed residual hyper T2 fluid-attenuated inversion recovery lesions in the perirolandic area, putamina, and medial thalami (most likely due to gliosis) with associated volume loss in the putamen and perirolandic cortex (representing necrosis; Fig 2F).

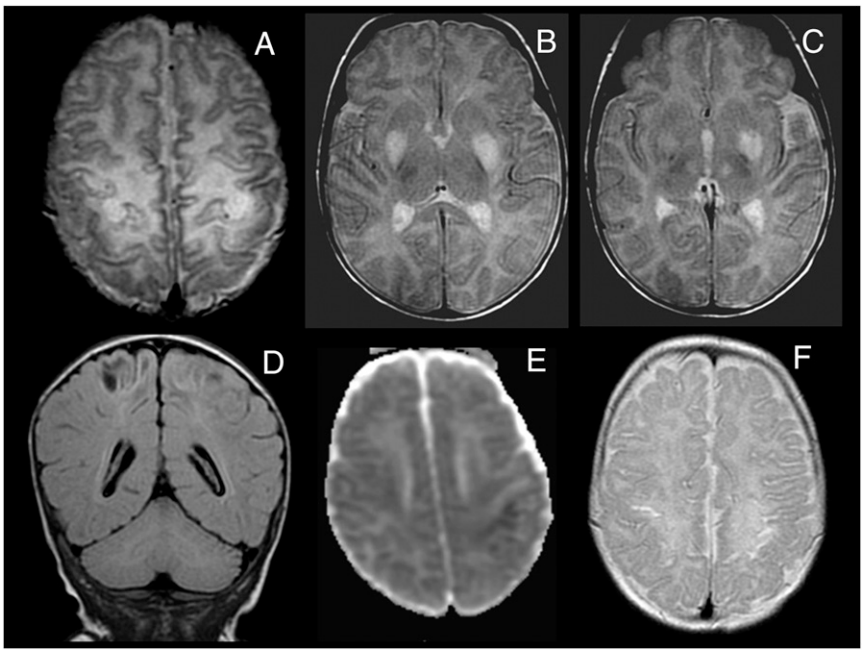

FIGURE 2
MRI of the patient at 1 month (A–E) and 6 months (F). Axial T2 at the level of the perirolandic region (A), putamina (B), and medial thalami (C) showing an abnormally high T2 signal. Coronal T2 fluid-attenuated inversion recovery (D) demonstrates abnormal hypointensity within the perirolandic lesions, suggesting chronic evolution. E, ADC map showing acute lesions in the left perirolandic region. F, Axial T2 at 6 months demonstrating perirolandic cortico-subcortical volume loss.

DISCUSSION

Thiamine is a vitamin that accumulates in target tissues by transport across the cell membrane using 2 carrier-mediated thiamine transporters: hTHTR1 (encoded by the *SLC19A2* gene) and hTHTR2 (encoded by the *SLC19A3* gene).[1] Mutations in these genes decrease the average rate of thiamine uptake in living cells and potentially lead to cellular thiamine deficiency.[5,6] The distributions of hTHTR1

and hTHTR2 in the body's tissues may explain the different phenotypes associated with each gene mutation, which are thiamine-responsive megaloblastic anemia[7] and acute and/or recurrent encephalopathy, respectively.[2–6]

Thiamine-diphosphate, the active vitamer of thiamine, is an essential cofactor of 3 mitochondrial enzymes: pyruvate dehydrogenase complex, α-ketoglutarate dehydrogenase, and branched-chain α-keto acid dehydrogenase.[8,9] These enzymes are involved in the oxidative decarboxylation of pyruvate, α-ketoglutarate, and branched-chain amino acids, respectively. The biochemical abnormalities detected in our patient, including lactic acidosis, high excretion of α-ketoglutarate, and increased levels of leucine and isoleucine, could be due to the decreased activity of these thiamine-dependent mitochondrial enzymes (Fig 3). Thus, thiamine administration normalized these activities. Increased α-ketoglutarate excretion seems to be a relevant biochemical hallmark of thiamine deficiencies because it has also been reported in patients with thiamine pyrophosphokinase deficiency[10] and mitochondrial thiamine pyrophosphate transporter SLC25A19 deficiency.[11] In accordance with these observations, experimental models suggest that α-ketoglutarate dehydrogenase is the most sensitive enzyme to thiamine deficiency.[8,12]

Branched-chain α-ketoacid excretion was normal. One explanation would be that the plasma isoleucine and leucine levels were only slightly increased and valine was normal. Consequently, the corresponding ketoacids were not detectable. These data contrast with biochemical abnormalities found in maple syrup urine disease, where a high amount of branched amino acid is associated with ketoacid excretion.

Our patient presented with a new phenotype caused by mutations in the *SLC19A3* gene that was characterized by acute encephalopathy and lactic acidosis in the neonatal period. Lactic acid accumulation has not been reported in other patients with thiamine transporter-2 deficiencies except in a 6-year-old girl with acute dystonia who showed a lactate peak on magnetic resonance spectroscopy.[4]

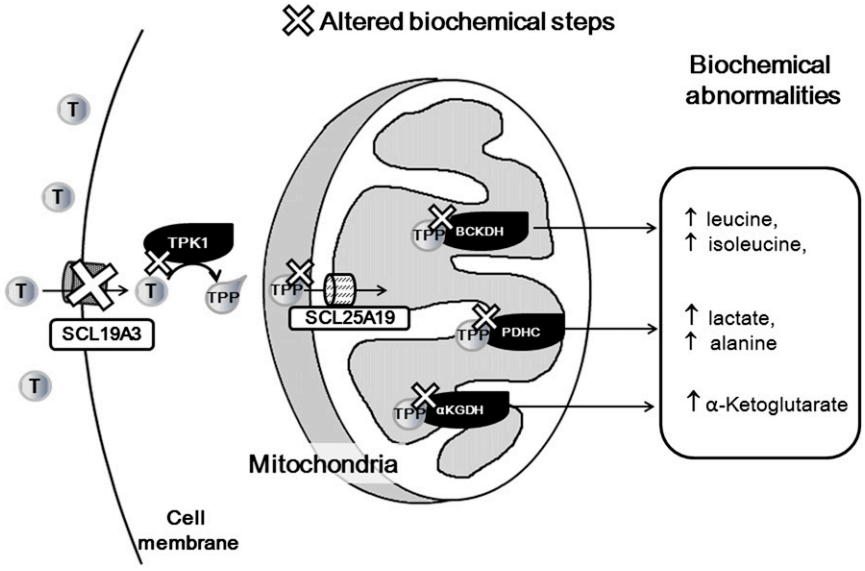

FIGURE 3
Altered thiamine metabolic pathways in our patient. αKGDH, α-ketoglutarate dehydrogenase; BCKDH, branched chain α-keto acid dehydrogenase PDHC, pyruvate dehydrogenase complex; T, thiamine; TPK1, thiamine pyrophosphokinase; TPP, thiamine pyrophosphate.

Neonatal lactic acidosis is a common manifestation of oxidative phosphorylation defects with a high mortality rate and no effective therapy in most cases.[13] Our clinical observations suggest that patients with hTHTR2 deficiency may be vulnerable to metabolic decompensation during the neonatal period when energy demands are high. In accordance with this hypothesis, severe lactic acidosis has been reported in newborns and infants with secondary thiamine deficiency due to total parenteral nutrition without vitamins[14] and exclusive soy-based formula diets.[15] These children showed vomiting, irritability, ophthalmoplegia, and lethargy. One patient also showed symmetric hyperintensities in the basal ganglia, mammillary bodies, and periaqueductal gray matter on MRI.[15] In all cases, treatment with thiamine resulted in the resolution of lactic acidosis and improved clinical symptoms within a few hours.

In reviewing the previous literature, 4 clinical and radiologic hTHTR2-related phenotypes are described, each with an age-related presentation (Fig 4). The infantile spasm phenotype most likely represents the final evolution of brain injury when treatment is not given at the onset of symptoms.[6] Moreover, the possibility of an earlier presentation during the intrauterine period cannot be ruled out because the metabolic deficiency is already present. The patient reported here had signs of fetal distress but, unfortunately, we do not have data on lactic acid concentrations at birth. Because some areas of the perirolandic cortex showed high ADC values, we suspect that these lesions had a chronic or subacute origin before the acute clinical presentation. It is possible that the stressful process of delivery was responsible for these lesions at birth but was not enough to trigger a metabolic crisis at that moment.

The perirolandic cortex pattern of involvement in our patient is different

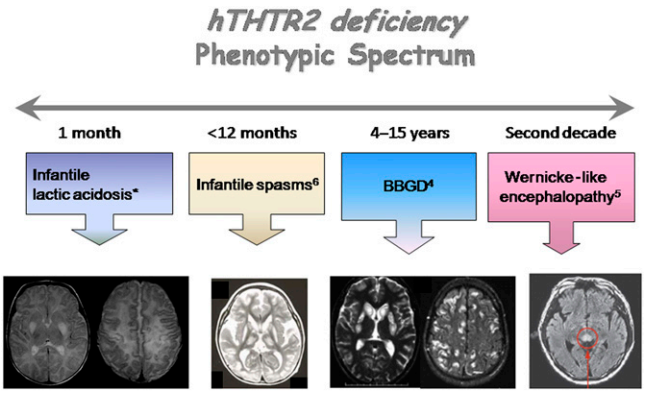

FIGURE 4
Phenotypic spectrum of hTHTR2 deficiency reported in the literature according to age of presentation and MRI features. *Patient in our report.

from the diffuse distribution of cortical lesions reported in older children with *SLC19A3* mutations.[4] We hypothesize that the pattern of injury in hTHTR2 deficiency depends largely on the regional variations in glucose metabolism at different ages, with the areas of higher metabolic demands being those with selectively greater vulnerability, as in other brain insults (eg, hypoxia-ischemia).[16] Thiamine deficiency due to insufficient cellular thiamine uptake might impair glucose metabolism within these structures.[17] The combination of signal abnormalities affecting the perirolandic cortex, putamen, and medial thalami observed in our patient has also been reported in children with Wernicke encephalopathy due to dietary thiamine deficiency,[18] thus suggesting a common pathologic mechanism for brain injury in both acquired (nutritional) and genetic conditions.

The benefit of biotin treatment in some patients with hTHTR2 deficiency has been established in previous studies. However, the mechanism of action remains unclear because experimental cell models have demonstrated that biotin is not a substrate for hTHTR2.[19] In our patient, biotin was discontinued after confirming the diagnosis, and he remains stable and in good metabolic control.

The homozygous p.Gly23Val mutation detected in our patient has already been described in a 1-year-old child with progressive loss of psychomotor milestones, rigidity, and dystonia.[1] Neurologic symptoms in this patient disappeared after biotin administration.[2] The lack of phenotype consistency in both children points toward other genetic and environmental factors modifying the expression of the disease among individuals with the same genotype.

In conclusion, this case report expands the phenotype of mutations in the *SLC19A3* gene to include thiamine defects in the differential diagnosis of newborns and infants with lactic acidosis because clinical response to the combination of thiamin and biotin was excellent in our patient.

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