Long-term outcome of isobutyryl-CoA dehydrogenase deficiency diagnosed following an episode of ketotic hypoglycaemia

Santra, S; Macdonald, A; Preece, M A; Olsen, R K; Andresen, B S

Published in: Molecular Genetics and Metabolism Reports

DOI: 10.1016/j.ymgmr.2016.11.005

Publication date: 2017

Document version: Final published version

Document license: CC BY-NC-ND

Citation for published version (APA): Santra, S., Macdonald, A., Preece, M. A., Olsen, R. K., & Andresen, B. S. (2017). Long-term outcome of isobutyryl-CoA dehydrogenase deficiency diagnosed following an episode of ketotic hypoglycaemia. Molecular Genetics and Metabolism Reports, 10, 28-30. https://doi.org/10.1016/j.ymgmr.2016.11.005

Terms of use: This work is brought to you by the University of Southern Denmark through the SDU Research Portal. Unless otherwise specified it has been shared according to the terms for self-archiving. If no other license is stated, these terms apply:

- You may download this work for personal use only.
- You may not further distribute the material or use it for any profit-making activity or commercial gain
- You may freely distribute the URL identifying this open access version

If you believe that this document breaches copyright please contact us providing details and we will investigate your claim. Please direct all enquiries to puresupport@bib.sdu.dk

Download date: 27. Apr. 2021
Case Report

Long-term outcome of isobutyryl-CoA dehydrogenase deficiency diagnosed following an episode of ketotic hypoglycaemia

S. Santra a,⁎, A. Macdonald b, M.A. Preece c, R.K. Olsen d, B.S. Andresen d,e

a Department of Clinical Inherited Metabolic Disorders, Birmingham Children’s Hospital, Steelhouse Lane, Birmingham B4 6NH, United Kingdom
b Department of Dietetics, Birmingham Children’s Hospital, Steelhouse Lane, Birmingham B4 6NH, United Kingdom
c Research Unit for Molecular Medicine, Department of Clinical Medicine, Aarhus University and Aarhus University Hospital, Aarhus, Denmark
d The Villum Center for Bioanalytical Sciences and Department of Biochemistry and Molecular Biology, University of Southern Denmark, Odense, Denmark
e E-mail address: Saikat.santra@bch.nhs.uk (S. Santra).

1. Introduction

Isobutyryl-CoA Dehydrogenase Deficiency (IBDD) is an inherited disorder of valine metabolism caused by mutations in ACAD8. Most reported patients have been diagnosed through newborn screening programmes due to elevated C4-carnitine levels and appear clinically asymptomatic. One reported non-screened patient had dilated cardiomyopathy and anaemia at the age of two years. We report a 13 month old girl diagnosed with IBDD after developing hypoglycaemic encephalopathy (blood glucose 1.9 mmol/l) during an episode of rotavirus-induced gastroenteritis. Metabolic investigations demonstrated an appropriate ketotic response (free fatty acids 2594 μmol/l, 3-hydroxybutyrate 3415 μmol/l), mildly elevated plasma lactate (3.4 mmol/l), increased C4-carnitine on blood spot and plasma acylcarnitine analysis and other metabolic abnormalities secondary to ketosis. After recovery, C4-carnitine remained increased and isobutyrylglycine was detected on urine organic acid analysis. Free carnitine was normal in all acylcarnitine samples. IBDD was confirmed by finding a homozygous c.845C>T substitution in ACAD8. The patient was given, but has not used, a glucose polymer emergency regimen and after ten years’ follow-up has had no further episodes of hypoglycaemia nor has she developed cardiomyopathy or anaemia. Psychomotor development has been normal to date. Though we suspect IBDD did not contribute to hypoglycaemia in this patient, patients should be followed-up carefully and glucose polymer emergency regimens may be indicated if recurrent episodes of hypoglycaemia occur.

This article does not contain any experimental studies with human or animal subjects performed by any of the authors and therefore ethical implications of the use of any new methods or technology are not discussed.

http://dx.doi.org/10.1016/j.ymgmr.2016.11.005
2214-4269/© 2016 The Authors. Published by Elsevier Inc. This is an open access article under the CC BY-NC-ND license (http://creativecommons.org/licenses/by-nc-nd/4.0/).
3.2. ACAD8/ACADS sequencing

PCR amplification of all ACAD8 exons and part of the flanking introns was performed as described elsewhere [9]. PCR fragments were sequenced in both directions on a 3100-Avant genetic analyzer using BigDye® Terminator v1.1 Cycle Sequencing kit, and using NM_014384.2 as a reference sequence.

Rare variants were identified based on a comparison against allelic frequencies from dbSNPv142, and Exome Aggregation Consortium (ExAC).

3. Results

3.1. Case report

The patient was a 13-month-old female who was born at term by normal spontaneous vaginal delivery to a mother of Pakistani origin. The patient’s maternal great-grandmother and paternal grandfather were first cousins. There had been no clinical or developmental concerns with the child over the first year of life. 48 h prior to admission she had received vaccination against measles, mumps and rubella and developed low-grade post-immunisation pyrexia. The next day she developed non-bilious vomiting and diarrhoea which continued for more than 24 h. At the same time, her appetite was poor and she drank water only. During the four hours prior to admission, the child was drowsy and difficult to rouse and she was brought to the hospital emergency department where initial investigations revealed a moderate metabolic acidosis (pH 7.29, base excess –8.5 mmol/l) with hypoglycaemic encephalopathy (blood glucose 1.9 mmol/l). She had rapid clinical improvement with intravenous dextrose administration and faecal analysis subsequently confirmed that rotavirus caused gastroenteritis. No further hypoglycaemia developed after reintroduction of oral feeding and she was discharged home three days later.

Metabolic investigations collected at the time of hypoglycaemia demonstrated an appropriate ketotic response (free fatty acids 2594 μmol/l, 3-hydroxybutyrate 3415 μmol/l) and mildly elevated lactate (3.4 mmol/l [reference range 0.6–2.6]). Blood spot and plasma acylcarnitine analysis revealed an unusually prominent peak of C4-carnitine as well as increases in a number of acylcarnitines secondary to ketosis. Free carnitine was normal (25 μmol/l [reference range 15–53]) Organic acids during illness demonstrated features of ketosis with grossly elevated 3-hydroxybutyrate and acetoacetate as well as a dicarboxylic aciduria.

After recovery, C4-carnitine remained increased and isobutyrylglycine was detected on urine organic acid analysis. Fatty acid oxidation flux studies demonstrated normal oxidation of myristate and oleate in cultured fibroblasts though there was evidence for a partial defect in short chain fatty acid oxidation (butyrate release 0.93 pmol CO₂/min/mg protein, normal controls 2.4–19.4).

3.2. ACAD8 and ACADS sequencing

DNA sequencing of ACAD8 identified a novel homozygous missense c.845C>T substitution. This is predicted to cause a single amino acid substitution of serine at position 282 to phenylalanine (p.Ser282Phe). The serine-282 residue is highly conserved across vertebrate species supporting the pathogenicity of this variant. This variant is reported to be deleterious in silico by both Polyphen and SIFT. Parental consent to DNA testing was not provided to confirm homozygosity. DNA sequencing of ACADS did not reveal any mutations.

3.3. Clinical course

The child was provided with a 15% glucose polymer emergency regimen once the diagnosis was suspected and this has been increased appropriately with age. No change was made to the child’s normal daily diet.

The child has been followed up regularly for the ten years since diagnosis and has remained well. There have been no further episodes of hypoglycaemia and in fact the emergency regimen has never actually been required. The child’s free carnitine has measured between 25 and 31 μmol/l on follow-up and carnitine supplementation has not been deemed necessary. Serial full blood count estimations have shown no sign of anaemia (Haemoglobin 127 g/l [reference range 120–160] at 11 years of age). Serial echocardiography has shown no evidence of cardiomyopathy over the ten years of follow-up with a shortening fraction in M-mode of 32% at 11 years of age. There have been no concerns about the child’s development and she has remained in mainstream education throughout.

4. Discussion

Persistent elevations of C4-carnitine may suggest disturbance in short chain fatty acid oxidation (e.g. SCADD) leading to butyrylcarnitine accumulation or a disturbance in valine metabolism (e.g. IBDD) leading to isobutyrylcarnitine accumulation. The overwhelming majority of patients with IBDD detected from newborn screening programmes have been clinically asymptomatic and it remains uncertain how significant SCADD is as a cause of hypoglycaemia in childhood, though disturbance in longer chain fatty acid oxidation is certainly associated with hypoglycaemia. This child presented with ketotic hypoglycaemic encephalopathy during an episode of gastroenteritis and metabolic abnormalities present at the time of hypoglycaemia were investigated further leading to a diagnosis of IBDD. It remains uncertain whether IBDD contributed to hypoglycaemia in this patient. Disturbed valine catabolism would not be expected to be associated with hypoglycaemia. IBDD is, however, one member of the acyl-CoA dehydrogenase family and there is significant sequence and structural similarity across members of this family [9]. Indeed it is recognised that some acyl-CoA dehydrogenases are able to catalyse the metabolism of substrates for other members of the family, with reduced affinity [1,10]. For example medium chain acyl-CoA dehydrogenase is known to have detectable but low activity towards longer chain acyl-CoA molecules. IBD and SCADD are also known to have some cross-reactivity with their respective substrates [1,11]. It is therefore tempting to suggest that IBDD and SCADD may have some cross-reactivity but cross-reactivity between an enzyme involved in amino acid catabolism and an enzyme involved in fatty acid oxidation has not been described. The structure of IBDD has been elegantly elucidated and whilst the structure shares many similarities to that of SCADD, the substrate binding site is wider to allow stable binding of molecules with a 2-methyl group rather than the narrower SCADD substrate binding site which favours straight-chain molecules [11]. Purified recombinant ACAD8 enzyme has been shown to be virtually inactive towards butyryl-CoA in vitro [9] however fibroblasts from this patient did demonstrate a partial defect in butyrate oxidation and the reason for this is uncertain.

Hypoglycaemia in IBDD has not been reported in other patients diagnosed from newborn screening programmes or otherwise, nor was it seen as a recurrent phenomenon in this child. Even if there were some ability of IBD to metabolise short chain fatty acids in vivo one would expect the normal activity of SCAD to compensate for deficiency of this seen in a patient with IBDD. With this in mind it is relevant to note that the first reported case of IBDD, and many other cases detected through newborn screening, have additionally been at least
heterozygous for the common c.625G > A variation in ACADS [4] which could conceivably have a bearing on the likelihood of clinical problems developing. This was not, however, the case in this child in whom ACADS’ sequencing revealed no pathogenic variant. Furthermore hypoglycaemia is known to complicate the clinical course of infants with severe rotavirus gastroenteritis even without any underlying inborn error of metabolism [12]. It is more likely, therefore, that this child’s hypoglycaemia was not primarily caused by IBDD although a contributing role of this condition in early life cannot be excluded. Some recently discovered inborn errors of metabolism have been shown to be associated with clinical symptoms only during infancy [13] with cases remaining asymptomatic in later life and it is conceivable that such mechanisms may also affect the expression of clinical symptoms in IBDD. Furthermore, the normal developmental, haematological and cardiac follow-up of this child suggests that previously reported learning difficulties, anaemia and cardiomyopathy are not necessarily proven associations with IBDD, though this child did not have systemic carnitine deficiency either at presentation or on follow-up.

5. Conclusions

In conclusion, the clinical significance of IBDD is uncertain and it remains a dilemma for clinicians managing children diagnosed through newborn screening programmes. Very few cases presenting with clinical symptoms are reported in the literature. We present the case of a child who was diagnosed through investigation for ketotic hypoglycaemia. In retrospect whilst it is unlikely that IBDD solely caused the hypoglycaemia in this patient, it is possible that this episode was more pronounced due to IBDD. Given the uncertainty of the natural history of IBDD, however, we would recommend patients are followed-up carefully and glucose polymer emergency regimens may be indicated if recurrent episodes of hypoglycaemia occur.

Conflict of interest

Dr. Saikat Santra, Mrs. Mary Anne Preece, Dr. Rikke K. Olsen and Prof. Brage S. Andresen declare that they have no conflict of interest. Professor Anita Macdonald has received research grants from Vitalfl and Nutricia and is on an advisory group for Nutricia.

Informed consent and animal rights

This article does not contain any experimental studies with human or animal subjects performed by any of the authors and therefore ethical approval was not required for this report. Informed consent for publication was obtained from the family of the child included in the report.

Details of the contributions of individual authors

All authors, have contributed to the planning, conduct, and reporting of the work described in this article. Dr. Saikat Santra as principal author will serve as guarantor for the article and accepts full responsibility for the work. Dr. Santra wrote the manuscript, has access to the data, and controlled the decision to publish. Professor Anita Macdonald reviewed the manuscript and contributed details of dietary management. Mrs. Mary Anne Preece reviewed the manuscript and contributed details of laboratory investigations. Dr. Rikke K. Olsen and Professor Brage S. Andresen reviewed the manuscript and contributed details of molecular investigations. The authors confirm independence from any sponsor; the content of the article has not been influenced by any sponsor.

References

[1] B.S. Andresen, et al., Isolated 2-methylbutyrylglycinuria caused by short/branched-chain acyl-CoA dehydrogenase (SCBAD) deficiency: identification of a new enzyme defect, resolution of its molecular basis and evidence for distinct acyl-CoA dehydrogenases in isoleucine and valine metabolism, Am. J. Hum. Genet. 67 (5) (2000) 1095–1103.
[2] D.D. Koeberl, et al., Rare disorders of metabolism with elevated butyryl- and isobutyryl-carnitine detected by tandem mass spectrometry newborn screening, Pediatr. Res. 54 (2) (2003) 219–223.
[3] J.O. Sass, S. Sandet, J. Zschocke, Isobutyryl-CoA dehydrogenase deficiency: isobutyrylglycinuria and ACAD8 gene mutations in two infants, J. Inherit. Metab. Dis. 27 (6) (2004) 741–745.
[4] C.B. Pedersen, et al., Variations in IBD (ACAD8) in children with elevated C4-carnitine detected by tandem mass spectrometry newborn screening, Pediatr. Res. 60 (2006) 315–320.
[5] J.W. Yun, et al., A novel ACAD8 mutation in asymptomatic patients with isobutyryl-CoA dehydrogenase deficiency and a review of the ACAD8 mutation spectrum, Clin. Genet. 87 (2) (2015) 196–198.
[6] D. Oglesbee, et al., Development of a newborn screening follow-up algorithm for the diagnosis of isobutyryl-CoA dehydrogenase deficiency, Genitourin. Med. 9 (2) (2007) 108–116.
[7] C.R. Roe, et al., Isolated isobutyryl-CoA dehydrogenase deficiency: an unrecognized defect in human valine metabolism, Mol. Genet. Metab. 65 (4) (1998) 264–271.
[8] I. Knerr, et al., Advances and challenges in the treatment of branched-chain amino/keto acid metabolic defects, J. Inherit. Metab. Dis. 35 (1) (2012) 29–40.
[9] T.V. Nguyen, et al., Identification of isobutyryl-CoA dehydrogenase and its deficiency in humans, Mol. Genet. Metab. 77 (1–2) (2002) 68–79.
[10] R.P. McAndrew, et al., Structural basis for substrate fatty acyl chain specificity: crystal structure of human very-long-chain acyl-CoA dehydrogenase, J. Biol. Chem. 283 (14) (2008) 9435–9443.
[11] K.P. Batalla, et al., Structures of isobutyryl-CoA dehydrogenase and enzyeme-product complex: comparison with isovaleryl- and short-chain acyl-CoA dehydrogenases, J. Biol. Chem. 279 (16) (2004) 16526–16534.
[12] P. Kaiser, et al., Complications in hospitalized children with acute gastroenteritis caused by rotavirus: a retrospective analysis, Eur. J. Pediatr. 171 (2) (2012) 337–345.
[13] C.D. van Karnebeek, et al., Mitochondrial carbonic anhydrase VA deficiency resulting from CASA alterations presents with hyperammonemia in early childhood, Am. J. Hum. Genet. 94 (3) (2014) 453–461.