Glycerol intoxication syndrome in young children, following the consumption of slush ice drinks

Shona LC Brothwell ,[1] Patricia E Fitzsimons,[2] Adam Gerrard,[1] Bernd C Schwahn,[3] Christopher Stockdale,[1] Ann Bowron,[4] Mark Anderson,[5] Claire E Hart ,[6] Romanie Hannah ,[7] Francesca Ritchie,[8] Sanjeev A Deshpande ,[9] Srividya Sreekantam ,[1] Gemma Watts,[10] Sufin Yap,[11] Helen Mundy,[12] Aravindan Veiraiah,[13] Abigail Collins,[14] Alison Cozens,[8] Andrew A Morris,[3] Ellen Crushell [15,16]

For numbered affiliations see end of article.

Correspondence to
Prof Ellen Crushell;
ellen.crushell@ucd.ie

SLB and PEF contributed equally.

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ABSTRACT

Introduction Slush ice drinks are commonly available refreshments, aimed at children and young people. Glycerol is used to maintain the slush effect in the absence of a high sugar content.

Objective To describe a series of children who became acutely unwell shortly after consuming a slush ice drink; their presentation mimics specific inherited metabolic diseases (IMDs).

Methods A retrospective case review of 21 children who presented to centres across the UK and Ireland from 2009 through 2024 was carried out.

Results Almost all of the children (93%) became unwell within 60 min of slush ice drink consumption. None had any relevant past medical history. The median age at presentation was 3 years 6 months (range 2 years – 6 years 9 months). Presenting features include acute decrease in consciousness (94%), hypoglycaemia (95%), metabolic (lactic) acidosis (94%), pseudohypertriglyceridaemia (89%) and hypokalaemia (75%). Glyceroluria was present in all acute urine organic acid samples. No underlying IMD was found in the 14 patients who underwent further enzymatic or genetic testing. The majority (95%) subsequently avoided slush ice drinks and did not have reoccurrence.

Conclusion Consumption of slush ice drinks containing glycerol may cause a clinical syndrome of glycerol intoxication in young children, characterised by decreased consciousness, hypoglycaemia, lactic acidosis, pseudohypertriglyceridaemia and hypokalaemia. This mimics inherited disorders of gluconeogenesis and glycerol metabolism. Clinicians and parents should be alert to the phenomenon, and public health bodies should ensure clear messaging regarding the fact that younger children, especially those under 8 years of age, should avoid slush ice drinks containing glycerol.

WHAT IS ALREADY KNOWN ON THIS TOPIC

⇒ Slush ice drinks are popular and targeted at children. Glycerol (E422) is used in sugar-free slush ice drinks to maintain the slush effect.
⇒ There are rare reports of glycerol intoxication in adults following ingestion or administration of large doses of glycerol.

WHAT THIS STUDY ADDS

⇒ This is the first detailed description of glycerol intoxication syndrome in a series of children. Onset occurred shortly after ingestion of a slush ice drink.
⇒ Clinical and biochemical features mimicked metabolic disease and included acutely decreased consciousness, hypoglycaemia and metabolic acidosis.
⇒ Glyceroluria (on urine organic acid analysis) and pseudohypertriglyceridaemia (reflecting glycerolaemia) are key acute biochemical markers.

HOW THIS STUDY MIGHT AFFECT RESEARCH, PRACTICE OR POLICY

⇒ This study may inform policy in relation to the use of glycerol in food and drinks and in issuing guidance for parents.
⇒ Cases in this series informed recent national guidance in the UK and Ireland in relation to slush ice drink consumption by young children.
⇒ This series illustrates the importance of obtaining acute hypoglycaemia investigations in the emergency department, including plasma triglyceride levels, when glycerol intoxication syndrome is suspected.

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INTRODUCTION

The clinical triad of decreased consciousness, hypoglycaemia and metabolic acidosis raises suspicion of possible toxin ingestion or an acute decompensation of an inherited metabolic disease (IMD). Rapid recognition and investigation of decreased consciousness and hypoglycaemia facilitates swift diagnosis of the underlying cause.[1] Where an underlying IMD is present, prompt diagnosis is critical to ensure optimal long-term management and outcomes. Here, we describe a series of children who presented to emergency departments acutely unwell with this clinical triad, after consumption of slush ice drinks containing glycerol.

METHODS

We retrospectively reviewed the medical notes of patients with a diagnosis of slush ice drink-related hypoglycaemia who presented to our tertiary

Table 1 Key clinical and biochemical characteristics of the patients in our cohort ('Yes': present; 'No': absent; 'Not known': not documented or not measured)

Features at presentation	Case 1	Case 2	Case 3	Case 4	Case 5	Case 6	Case 7	Case 8	Case 9	Case 10
Decreased consciousness	Yes	Yes	Yes	Yes	Yes	Yes	Not known	Yes	Yes	Yes
Hypoglycaemia	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Metabolic acidosis	Yes	Yes	Yes	Yes	Yes	Not known	Yes	Not known	Not known	Yes
Elevated lactate	Yes	Yes	No	Yes	Yes	Not known	Yes	Yes	Yes	Yes
Hypokalaemia	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	Not known	Yes
Glyceroluria	Yes	Yes	Yes	Yes	No (delayed)	Yes	Yes	Yes	Not known	Yes
History of hypoglycaemia	No	No	No	No	No	No	No	No	No	No
Reoccurrence	No	No	No	No	No	No	No	Yes with slush	No	No

Features at presentation	Case 11	Case 12	Case 13	Case 14	Case 15	Case 16	Case 17	Case 18	Case 19	Case 20	Case 21
Decreased consciousness	Yes	Yes	Yes	Yes	No	Not known	Not known	Not known	Yes	Yes	Yes
Hypoglycaemia	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Metabolic Acidosis	Yes	Yes	Not known	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes
Elevated lactate	Yes	Yes	Not known	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Hypokalaemia	Not known	Yes	Not known	No	Not known	No	Yes	Yes	Yes	No	Not known
Glyceroluria	Yes	Yes	Yes	Yes	Not known	Yes	Yes	Yes	Not known	Yes	Yes
History of hypoglycaemia	No	No	No	No	No	No	No	No	No	No	No
Reoccurrence	No	No	No	No	No	No	No	No	No	No	No

metabolic services from 2009 through 2024. These patients were referred by paediatricians for metabolic review owing to the clinical history and abnormal hypoglycaemia investigations following the acute presentation to emergency departments.

Diagnosis of slush ice drink-related hypoglycaemia was based on the presence of an antecedent history of slush ice drink ingestion and clinical features, accompanied by laboratory confirmation of at least two of the following: (1) hypoglycaemia, (2) metabolic acidosis, (3) glyceroluria, and supported by negative biochemical, enzymology and/or genetic testing for underlying IMDs.

Data regarding history, clinical features, biochemistry and management were recorded. As with other newly recognised clinical syndromes, the first cases had a more extensive investigative work-up than more recent cases, after recognition of the syndrome and sharing of cases at medical conferences. The CARE (CAse REport) reporting guidelines were used.[2]

RESULTS

Clinical and biochemical data for 21 cases across nine centres in the UK and Ireland were reviewed. Table 1 summarises the key clinical and biochemical characteristics. Information regarding sex was available for 18 patients; 56% of these were male (n=10) and 44% were female (n=8). At the time of presentation, the median age was 3 years 6 months (range 2 years – 6 years 9 months); 38% of the patients were aged ≥4 years (n=8), and two patients (10%) were aged ≥5 years.

None of the patients had any history of hypoglycaemia or other relevant condition. None had been significantly unwell, although the dietetic history in two patients indicated a period of fasting in the hours preceding the slush ice drink ingestion, and suggested rapid consumption of the drink. Two patients had minor head injuries at play parks in the hours before the slush ice drink consumption. One patient had a cough and one episode of loose stool prior to consuming the slush ice drink.

Information was available regarding the time of onset in relation to the slush ice drink consumption for 15 patients; 14 of these (93%) became unwell within 60 min of ingestion. Information about consciousness level at presentation was available for 17 patients; 16 of these (94%) demonstrated an acute decrease in consciousness. One patient had a generalised tonic clonic seizure. Urgent neuroimaging was carried out in 4 (33%) of 12 patients; no other cause for decreased consciousness was found in any patient.

Twenty children (95%) had documented hypoglycaemia at presentation (blood glucose ≤2.6 mmol/ L); the blood glucose was <1.5 mmol/L in 13 (65%) of these, indicating severe hypoglycaemia. The median blood glucose was 1.2 mmol/L (range 0–3.3 mmol/L).

Metabolic acidosis was present in 16 (94%) of the 17 patients for whom this information was available. The median pH at presentation (for the 13 patients in whom pH was recorded) was 7.21 (range 7.16–7.26). Nineteen patients had a documented initial lactate level; this was elevated >3.0 mmol/L in 18 patients (95%). The median lactate was 4.3 mmol/L (range 2.5–7.5 mmol/L).

Potassium level was available for 16 patients; 75% of these had hypokalaemia at presentation (n=12). The median potassium level was 2.7 mmol/L (range 2.2–3.9 mmol/L).

Of the nine patients who had plasma triglycerides measured at presentation, 89% (n=8) had transient pseudohypertriglyceridaemia. The median triglyceride level was 19.5 mmol/L (range 10.85–25.6 mmol/L; n=6). The normal range for triglycerides is 0.35–1.49 mmol/L.

Free fatty acids (FFA) and 3-hydroxybutyrate (3-OHB) were measured in eight patients; 75% (n=6) of these had an elevated FFA:3-OHB ratio (>2). The median FFA level was 2668 µmol/L (range 1239–3361 µmol/L; n=5), and the median 3-OHB level was 564 µmol/L (range 291–1051 µmolL; n=5).

Urine was obtained at presentation for organic acid analysis in 17 patients; all of these samples were abnormal and demonstrated a large glycerol peak (glyceroluria). Other consistent changes seen in the urine organic acid profiles include elevated lactate (n=15; 88%) and ketonuria (n=10; 59%). The remaining four patients either did not have a sample taken (n=3), or the sample was obtained >24 hours after presentation and therefore did not capture acute biochemical changes (n=1). None of the urine samples obtained at follow-up

appointments (when patients were well) demonstrated glyceroluria (n=4).

Three patients had functional enzyme studies carried out, all of which confirmed normal fructose-1,6-bisphosphatase (FBPase) activity. Due to the possibility of an underlying IMD, genetic testing was undertaken in 14 patients. The genetic testing strategy varied according to regional practice. Nine patients underwent targeted testing with appropriate gene panels (64%) and five patients underwent whole exome/genome sequencing (36%). The results were negative in all patients with no genetic evidence of an underlying IMD.

Following the acute admission for hypoglycaemia management and monitoring, patients were discharged with advice to avoid slush ice drinks. The majority of patients (95%; n=20) subsequently avoided slush ice drinks and had no further episodes of hypoglycaemia. However, one patient drank another slush ice drink (at the age of 7 years 3 months), and became symptomatic within an hour, rapidly progressing to vomiting and drowsiness. Recognising the symptoms and likely link to the slush ice drink, the parents gave a glucose polymer drink (S.O.S 20 (Vitaflo); provided to them in clinic after the initial presentation), and called an ambulance. When the paramedics arrived, the blood glucose was normal and symptoms were resolving, so the child was not transferred for further assessment or investigations.

DISCUSSION

Patients in this series were identified through regional metabolic teams due to the clinical and biochemical phenotype, which mimics specific IMDs. Glyceroluria was a consistent finding; this is a characteristic feature of specific IMDs, such as FBPase deficiency (disorder of gluconeogenesis) and isolated X-linked glycerol kinase (GK) deficiency (disorder of glycerol metabolism).[3 4] However, glyceroluria may be caused by exogenous sources, such as glycerol in nappy cream (which directly contaminates urine samples) and glycerol ingested in some enteral medication (eg, some paracetamol formulations and glycerol phenylbutyrate), food and drink.[5]

Slush ice drinks are popular, brightly coloured soft drinks, designed to appeal to children and young people. They are sold in locations frequented by children and young people, including newsagents, parks and soft play/ trampolining centres. Some brands sell kits which enable members of the public to make slush ice drinks at home. Slush ice drink ingredients vary, but the majority available in the UK and Ireland are marketed as 'no added sugar' or 'sugar free'. Some contain fructose in the form of fruit juice or corn syrup. Varieties which are sugar free or have no added sugar contain glycerol (E422; also referred to as glycerin) in order to maintain the slush effect, along with additional sweeteners such as stevia or sucralose (E955; also a source of fructose).

Glycerol occurs naturally in lipids and is an endogenous metabolite in mammals. When consumed enterally it is rapidly absorbed from the gastrointestinal tract, distributed into the total body water space and primarily metabolised in the liver. Glycerol is used as an energy substrate via glycolysis or participates in gluconeogenesis and lipogenesis. Glycerol is oxidised and exhaled as carbon dioxide, with minimal excretion via urine or faeces. Excretion in urine occurs following administration of high-dose glycerol.[6] Glycerol has generally been thought to be safe in humans; it is an authorised group I food additive in the EU, in accordance with Annex II and Annex III of Regulation (EC) number 1333/2008, and can be used at *quantum satis*.[7–9] However, there are rare reports of glycerol intoxication syndrome (GIS) following ingestion or administration of large doses of glycerol.[10]

The patients reported here all presented shortly after consuming slush ice drinks containing glycerol; the other ingredients varied depending on the brand. Although ingredients are listed on several brands' websites, there is poor transparency around glycerol concentration. Dosing or mixing errors (leading to a higher concentration of glycerol) might possibly have been involved in some of our cases. However, in at least one case where a child rapidly consumed a large quantity of slush ice drink, environmental health officers promptly visited the site and confirmed the slush ice drink machine was operating correctly and the drink was 'ready to use' (no preparation or risk of dosing errors).

The clinical and biochemical phenotype of the children in this series is remarkably consistent and occurred shortly after slush ice drink consumption. Almost all patients presented with acutely decreased consciousness, hypoglycaemia and metabolic (lactic) acidosis. Other consistent biochemical features included hypokalaemia, elevated FFA:3-OHB ratio, pseudohypertriglyceridaemia and glyceroluria. Pseudohypertriglyceridaemia (high measured triglyceride levels in a sample with a low lipaemic index) occurs owing to overestimation of the serum triglyceride levels due to the laboratory assay used, which measures glycerol after hydrolysis of triglycerides, rather than triglycerides directly.[11] Pseudohypertriglyceridaemia is therefore an important diagnostic clue on the acute blood samples in these cases, although this does not negate the need for acute urine sampling for organic acids, as part of the hypoglycaemia screen.

Patients with FBPase deficiency and GK deficiency may present with a similar clinical and biochemical phenotype, and diagnosis is confirmed through enzymatic and/or genetic testing. Isolated GK deficiency is usually mild, and pseudohypertriglyceridaemia and glyceroluria are persistent, even in well, non-decompensated patients. In FBPase deficiency, these biochemical features are usually seen only during acute metabolic decompensation.[4 5 12] An elevated FFA:3-OHB ratio has been described in fasting patients with FBPase deficiency.[3 13] There are other rare IMDs which may present in a similar manner, but with important differences. Glycerol-3-phosphate dehydrogenase (GPD1) deficiency, another disorder of glycerol metabolism, is less well described; features include transient infantile hypertriglyceridaemia, ketotic hypoglycaemia, glyceroluria, hepatomegaly and hepatic fibrosis.[12] Hereditary fructose intolerance, an inherited disorder of fructose metabolism, is characterised by acute crises with hypoglycaemia, lactic acidosis and gastrointestinal symptoms after ingesting fructose (and fructose-containing ingredients such as sucrose, sorbitol and sucralose). However, patients typically present at weaning, when fructose-containing foods are introduced into the diet, and glyceroluria is not a feature of hereditary fructose intolerance.[14 15] This series emphasises the importance of obtaining appropriate biochemical samples at the time of the acute presentation, to guide accurate diagnosis, management and follow-up.

GIS is not well defined; very few cases have been reported in the literature and the specific pathophysiology remains unknown.[10 16–20] Episodes in adults were triggered by rapid and large doses of glycerol intake with or without catabolism, and characterised by metabolic acidosis and lethargy, which may progress to coma and seizures. Patients may also be hypothermic.[5] Adults develop hypoglycaemia less readily than children, and this was not a feature in two adult cases of GIS reported in the literature, though both had profound neurological symptoms.[18–20] These were postulated to be due

to intracellular dehydration caused by the osmotic effect of glycerol.[18–20] After oral ingestion of glycerol, a maximum effect on plasma osmolarity is found at approximately 80 min. This timing correlates with the maximum reduction in intracranial pressure seen following enteral high-dose glycerol administration in patients with traumatic brain injury.[6 21] We do not have acute osmolality measurements in our patients; we therefore cannot exclude the possibility that osmotic effects contributed to their decreased consciousness.[18–20]

As with FBPase deficiency, the biochemical findings in GIS include transient glyceroluria and pseudohypertriglyceridaemia. None of our patients had any history of significant intercurrent illness on the day of presentation, although several had a history of increased physical activity and two were in a relatively fasting state. Our patients all swiftly recovered after initial resuscitation and hypoglycaemia management, and none of those who subsequently avoided slush ice drinks have had any further episodes. Repeat urine organic acid analysis carried out when these children had fully recovered confirmed that the glyceroluria was transient, and results were negative in all who underwent genetic or enzymatic testing. We therefore conclude, based on the available evidence, that the patients in this series became acutely unwell due to glycerol intoxication. The reasons why this cohort of children were susceptible to GIS are probably multifactorial and may include environmental, situational, physiological and genetic influences.

The clinical and biochemical phenotype described in our patients demonstrates that GIS particularly mimics FBPase deficiency; further research is required to elucidate the mechanisms underlying the aberrant biochemistry. We postulate that it might reflect increased sensitivity of the FBPase enzyme to inhibition by glycerol-3-phosphate in young children, dysregulated NADH/NAD+ dependent recycling between dihydroacetone phosphate and glycerol-3-phosphate, or delayed maturation of other enzymes of glycerol or gluconeogenesis metabolic pathways. Reduced enzyme function due to haploinsufficiency is unlikely but cannot be ruled out, although FBPase enzyme activity was normal in all patients in this cohort who were tested (n=3). Of the 14 cases where genetics were performed, both copies of *FBP1* and/or *GK* genes were present and without variants.

Glycerol is an osmotic agent; a characteristic which has been exploited in the past in neurosurgery and ophthalmological surgery to reduce intracranial and intraocular pressure respectively.[6 21] However, its use has not been systematically studied in children. The hypokalaemia noted in this cohort may be due to the osmotic effect of glycerol causing intracellular potassium shift; alternatively, glycerol may exert an osmotic diuretic effect resulting in renal tubular loss of potassium. It is also possible that some of the biochemical features seen in our patients are caused by other ingredients (*Stevia rebaundiana,* for example, which has been reported to induce insulin secretion,[22 23] although this was not a consistent ingredient in all brands, and no hyperinsulinism was detected).

Although slush ice drinks have been around for some time, there are no published medical reports regarding this associated GIS. A cause of the recent apparent surge in cases may be the reduced sugar content of these drinks, secondary to two main factors: first, public health and parental concerns about high sugar ingestion, and second, the introduction of a 'sugar tax' on high sugar (>5%)-containing drinks in Ireland and the UK in 2018 and 2019, respectively. Slush ice drinks in countries without a sugar tax typically contain a much higher glucose content, and many do not contain glycerol at all. With the exception of one patient, who presented in 2009, the other patients in our series presented between 2018 and 2024, coincident with the introduction of the sugar tax.

This clinical syndrome following slush ice drink ingestion has been highlighted recently to public health bodies and the media, based on cases included in this series. In 2023, the UK Food Standards Agency recommended that children aged ≤4 years should not be given slush ice drinks containing glycerol, and that children aged ≤10 years should not have more than one slush ice drink.[24] The Food Safety Authority of Ireland (FSAI) followed suit with similar guidance in 2024.[25] There is poor transparency around slush ice drink glycerol concentration; estimating a safe dose is therefore not easy. It is also likely that speed and dose of ingestion, along with other aspects such as whether the drink is consumed alongside a meal or during a fasting state, or consumed after high-intensity exercise, may be contributing factors.[8] Food Standards Scotland and the FSAI suggested that 125 mg/kg of body weight per hour is the lowest dose that is associated with negative health effects. For a toddler this may equate to 50–220 mL of a slush ice drink. The standard size drink sold in the UK and Ireland is 500 mL.

From a public health perspective, there are no nutritional or health benefits from these drinks and they are not recommended as part of a balanced diet. Recommendations on their safe consumption therefore need to be weighted towards safety. To ensure safe population-level recommendations can be easily interpreted at the individual parental level, and given the variability across an age cohort of weight, we suggest that recommendations should be based on weight rather than age. Alternatively, the recommended age threshold may need to be higher (8 years), to ensure the dose per weight would not be exceeded given normal population variation in weight.

Based on experience with early cases, the UK National Poisons Information Service changed its advice. A new page on slush ice drinks and a specific alert about glycerol were added to TOXBASE,[26] the information resource that is accessed by healthcare staff while managing poisoning in the UK. An online enquiry was later added to TOXBASE to facilitate more feedback about potential cases of glycerol intoxication.

CONCLUSION

Healthcare professionals and parents should be aware that young children can become seriously unwell due to glycerol intoxication, shortly after consuming slush ice drinks containing glycerol. Features include decreased consciousness, hypoglycaemia, metabolic (lactic) acidosis, pseudohypertriglyceridaemia, hypokalaemia and glyceroluria. This clinical and biochemical phenotype mimics specific IMDs; it is therefore important for clinicians to obtain appropriate investigations at the time of presentation (including urine for organic acid analysis), and discuss the situation with their regional metabolic service. This case series should also inform public health bodies and food safety authorities when making recommendations on glycerol ingestion in young children, with an emphasis on safety.

Author affiliations
[1]Department of Paediatric Inherited Metabolic Medicine, Birmingham Women's and Children's NHS Foundation Trust, Birmingham, UK
[2]Department of Laboratory Medicine, Children's Health Ireland at Temple Street, Dublin, Ireland
[3]Willink Metabolic Unit, Royal Manchester Children's Hospital, Manchester, UK
[4]Department of Blood Sciences, Newcastle Upon Tyne Hospitals NHS Foundation Trust, Newcastle Upon Tyne, UK
[5]Department of Paediatric Medicine, Newcastle Upon Tyne Hospitals NHS Foundation Trust, Newcastle Upon Tyne, UK
[6]Department of Clinical Chemistry and Newborn Screening, Sheffield Children's Hospital NHS Foundation Trust, Sheffield, UK

[7]Department of Paediatric Emergency Medicine, Brighton and Sussex University Hospitals NHS Trust, Brighton, UK
[8]Department of Paediatric Inherited Metabolic Medicine, Royal Hospital for Children and Young People, Edinburgh, UK
[9]Department of Paediatrics, Shrewsbury and Telford Hospital NHS Trust, Telford, UK
[10]Department of Paediatrics, Portsmouth Hospitals University NHS Trust, Portsmouth, UK
[11]Department of Paediatric Inherited Metabolic Medicine, Sheffield Children's Hospital NHS Foundation Trust, Sheffield, UK
[12]Department of Paediatric Inherited Metabolic Medicine, Evelina London Children's Hospital, London, UK
[13]National Poisons Information Service, NHS Lothian, Edinburgh, UK
[14]Child Health Public Health, Health Service Executive, Dublin, Ireland
[15]Department of Paediatrics, School of Medicine, University College Dublin, Dublin, Ireland
[16]National Centre for Inherited Metabolic Disorders, Children's Health Ireland at Temple Street, Dublin, Ireland

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ORCID iDs
Shona LC Brothwell http://orcid.org/0009-0004-7365-7940
Claire E Hart http://orcid.org/0000-0002-6863-2341
Romanie Hannah http://orcid.org/0000-0002-3940-0066
Sanjeev A Deshpande http://orcid.org/0009-0000-9399-1074
Srividya Sreekantam http://orcid.org/0000-0003-3721-3838
Ellen Crushell http://orcid.org/0000-0003-3768-8569

REFERENCES

1 The Royal College of Paediatrics and Child Health Guideline: the management of children and young people with an acute decrease in conscious level. A nationally developed evidence-based guideline for practitioners. Available: https://www.rcpch.ac.uk/sites/default/files/2019-04/decon_guideline_revised_2019_08.04.19.pdf
2 Gagnier JJ, Kienle G, Altman DG, *et al*. The CARE guidelines: consensus-based clinical case reporting guideline development.
3 Steinmann B, Santer R. Disorders of fructose metabolism. In: Saudubray JM, Baumgartner MR, García-Cazorla Á, *et al*, eds. *Inborn Metabolic Diseases 7th Ed*. Springer, 2022.
4 Steinmann B, Gitzelmann R, Berghe G. Disorders of fructose metabolism. In: Valle DL, Antonarakis S, Ballabio A, *et al*, eds. *The Online Metabolic and Molecular Basis of Inherited Diseases*. New York: McGraw Hill, 2019.
5 Zschocke J, Hoffman GF. Metabolic pathways and their disorders: carbohydrate metabolism. In: *Vademecum Metabolicum 5th Edition*. Thieme, 2021.
6 McCurdy DK, Schneider B, Scheie HG. Oral glycerol: the mechanism of intraocular hypotension. *Am J Ophthalmol* 1966;61:1244–9.
7 Regulation (EC) no 1333/2008 of the European parliament and of the council of 16 December 2008 on food additives (2008) official journal of the European Union l 354, p. 16. 2008. Available: http://data.europa.eu/eli/reg/2008/1333/oj
8 Re-evaluation of glycerol (E422) as a food additive. *EFSA Journal* 2017;15:4720. Available: https://efsa.onlinelibrary.wiley.com/doi/epdf/10.2903/j.efsa.2017.4720
9 Follow up of the re-evaluation of glycerol (E422) as a food additive. *EFSA Journal* 2022;20:7353. Available: https://efsa.onlinelibrary.wiley.com/doi/epdf/10.2903/j.efsa.2022.7353
10 Maclaren NK, Cowles C, Ozand PT, *et al*. Glycerol intolerance in a child with intermittent hypoglycemia. *J Pediatr* 1975;86:43–9.
11 Backes JM, Dayspring TD, Hoefner DM, *et al*. Identifying pseudohypertriglyceridemia in clinical practice. *Clin Lipidol* 2014;9:625–41.
12 Wu JW, Yang H, Wang SP, *et al*. Inborn errors of cytoplasmic triglyceride metabolism. *J Inherit Metab Dis* 2015;38:85–98.
13 Morris AA, Deshphande S, Ward-Platt MP, *et al*. Impaired ketogenesis in fructose-1,6-bisphosphatase deficiency: a pitfall in the investigation of hypoglycaemia. *J Inherit Metab Dis* 1995;18:28–32.
14 Singh SK, Sarma MS. Hereditary fructose intolerance: A comprehensive review. *World J Clin Pediatr* 2022;11:321–9.
15 Gaughan S, Ayres L, Baker PR, *et al*. Hereditary fructose intolerance. In: *GeneReviews, Amemiya (Ed.)*. 2021.
16 Beatty ME, Zhang YH, McCabe ER, *et al*. Fructose-1,6-diphosphatase deficiency and glyceroluria: one possible etiology for GIS. *Mol Genet Metab* 2000;69:338–40.
17 Dipple KM, McCabe ER. Disorders of glycerol metabolism. In: Blau N, Leonard J, Hoffmann GF, *et al*, eds. *Physician's Guide to the Treatment and Follow-Up of Metabolic Diseases*. Springer, 2006.
18 Bingel U, Andresen H, Liepert J. Acute encephalopathy due to glycerol over-consumption. *J Neurol* 2006;253:125–6.
19 Andresen H, Bingel U, Streichert T, *et al*. Severe glycerol intoxication after Menière's disease diagnostic--case report and overview of kinetic data. *Clin Toxicol (Phila)* 2009;47:312–6.
20 Coulson L, Surla A, Tran V, *et al*. Severe glycerol intoxication mimicking toxic alcohol ingestion following large volume consumption of vanilla essence. *Clin Toxicol (Phila)* 2022;60:1248–50.
21 Wald SL, McLaurin RL. Oral glycerol for the treatment of traumatic intracranial hypertension. *J Neurosurg* 1982;56:323–31.
22 Misra H, Soni M, Silawat N, *et al*. Antidiabetic activity of medium-polar extract from the leaves of Stevia rebaudiana Bert. (Bertoni) on alloxan-induced diabetic rats. *J Pharm Bioall Sci* 2011;3:242.
23 Jeppesen PB, Gregersen S, Rolfsen SED, *et al*. Antihyperglycemic and blood pressure-reducing effects of stevioside in the diabetic Goto-Kakizaki rat. *Metab Clin Exp* 2003;52:372–8.
24 Food Standards Agency. Not suitable for under-4s': new industry guidance issued on glycerol in slush-ice drinks. 2023. Available: https://www.food.gov.uk/print/pdf/node/19811
25 Food Safety Authority of Ireland. Advice for consumers regarding consumption of slush ice drinks. n.d. Available: https://www.fsai.ie/consumer-advice/food-safety-and-hygiene/advice-for-consumers-regarding-consumption-of-slus
26 UK national poisons information service TOXBASE. n.d. Available: https://www.toxbase.org/login/?ReturnUrl=/