SCIENTIFIC LITERATURE

Diazoxide Toxicity in Congenital Hyperinsulinism: A Seldom-Considered Rare Side Effect

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ABSTRACT

Diazoxide is the sole approved drug for congenital hyperinsulinism; however, diuretic administration and vigilant monitoring are crucial to prevent and promptly identify potentially life-threatening adverse effects. This report aims to highlight a seldom-considered rare side effect of diazoxide.

INTRODUCTION

Congenital Hyperinsulinism (CHI) comprises a rare group of hypoketotic hypoglycemia disorders, characterized by abnormal insulin secretion leading to transient or persistent hypoglycemia [1]. While transient forms are linked to perinatal factors (i.e. Infant of diabetic mother, intrauterine growth retardation, maternal toxemia, birth asphyxia and perinatal stress) and can resolve rapidly (lasting less then 6 months), persisting forms of CHI typically persist beyond 6 months of age and are often associated with mutations in genes involved in regulating pancreatic β-cell function (e.g. ABCC8, KCNJ11, GLUD1, GCK, HADH, SLC16A1, HNF4A, HNF1A, HK1, PGM1, PMM2..) or genetic syndromes (e.g. Beckwith Wiedemann); however in some of these forms the exact genetic cause remains unknown [2]. If misdiagnosed, this condition can lead to irreversible brain damage [3]. The treatment of CHI depends on the underlying condition and can be medical, surgical or both. Currently, the only approved treatment for CHI is diazoxide, though some patients may be resistant or intolerant, necessitating alternative options [4,5]. Surgical intervention may be curative in focal forms of CHI [6], while others can benefit from administration of continuous enteral glucose or drugs such as octreotide or its long-acting analogs [7]. This report aims to describe a rare side effect of diazoxide that, though documented in literature, lacks defined incidence, pathogenesis, and timing of appearance.

CASE PRESENTATION

The patient is the only child of non-consanguineous parents. Born at 39 gestational weeks through eutocic delivery, he weighed 3300 g (41st weight percentile, -0.24 SDS) and measured 51 cm in length (66th length percentile, 0.4 SDS). The pregnancy was uneventful and no physical abnormalities were observed at birth. At two hours of

01

SCIENTIFIC LITERATURE

life, the infant exhibited hyporeactivity and difficulty in sucking. A blood gas analysis revealed a blood glucose level of 11 mg/dl. Consequently, early enteral feeding with both breast and formula milk was initiated. Despite these measures, persistent hypoglycemia necessitated his transfer to the Neonatal Intensive Care Unit (NICU). Intravenous (IV) infusion therapy with a 10% glucose solution was initiated, but hypoglycemia persisted. Subsequently, IV infusion with glucose 33% was administered via an umbilical venous catheter, gradually increased to 50%, achieving an IV Glucose Infusion Rate (GIR) of 10.4 mg/kg/min. Simultaneously, enteral feeding was supplemented first with fortified breast milk, then with formula milk containing a high-calorie glucolipid preparation, and finally with maltodextrins, resulting in an increased GIR of 15.3 mg/kg/min. On the 4th day of life, blood tests and a glucagon test during hypoglycemia strongly suggested CHI (Table 1-2).

Table 1: Blood tests during relative hypoglycemia.					
Glycemia	Insulin	C-peptide	ACTH	Cortisol	GH
46 mg/dL (nv>70mg/dL)	14.4 mcU/mL (nv<1.25 mcU/mL)	2 ng/mL (nv<0.5 ng/mL)	17.1 pg/mL (nv 4.7-48.8 pg/mL)	17 mcg/dL (nv > 18 mcg/dl)	7.76 ng/ml (nv >8 ng/ml)

Table 2: Glucagon stimulation test.		
Glycemia before	Glucagon administration	Glycemia 10' after
36 mg/dL (nv>70 mg/dL)	1 mg IM	85 mg/dL

Due to the high suspicion of CHI, subsequent genetic analysis was carried out and identified a heterozygous variant, c.4477C>T p.(Arg1493Trp), in the ABCC8 gene, inherited from the father and classified as a pathogenetic variant. On 22nd day of life, diazoxide and thiazide treatment was initiated, with diazoxide gradually increased to 15 mg/kg/day (administered in three daily doses), resulting in a partial improvement in the glycemic profile. IV glucose infusion was no longer required, but the patient still experienced blood sugar levels <70 mg/dL 2-3 times/day, leading to suspicion of a resistant-diazoxide form. For this reason the patient was addressed to our center. Before discharge, a cardiac Ultrasound Scan (US) showed normal results, and thiazide treatment was discontinued. Once admitted to our center (45th day of life), we conducted glucose monitoring without altering the ongoing treatment (diazoxide 15mg/kg/day). We opted not to reintroduce thiazide, considering the baby's age and the

normal findings of the recent cardiac US. The baby showed poor glycemic control (average glycemia 40-60 mg/dl), so a second-line therapy with subcutaneous octreotide was started. Octreotide was administered at an initial dosage of 5 mcg/kg/day in three daily administrations. After four days, the patient developed tachypnea (RR 70 breaths/min), intercostal, subcostal and jugular retractions, tachycardia (180-190 bpm), diuresis contraction (0.6-0.7 ml/kg/h) and mild increase in body weight, with adequate oxygen saturation in room air. Due to respiratory distress, high-flow oxygen therapy (maximum flow 10 l/min, maximum FiO2 0.25%) was initiated. Considering the acute presentation and the uncertain etiology of the symptoms, the infant was transferred to the NICU for intensive observation. Urgent laboratory-instrumental tests were performed due to the clinical conditions: results indicated normal cell blood count, electrolytes, renal-liver function and inflammatory indexes, blood culture resulted negative, blood gas analysis showed respiratory alkalosis, leading us to exclude sepsis and infective etiologies. Considering the recent introduction of octreotide, an abdominal X-ray was performed that ruled out Necrotizing Enterocolitis (NEC); the chest X-ray revealed an enlargement of the cardiac image beyond normal limits with clear lungs and pleural spaces (Figure 1).
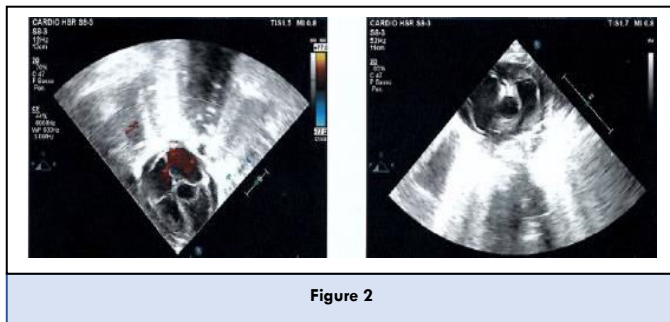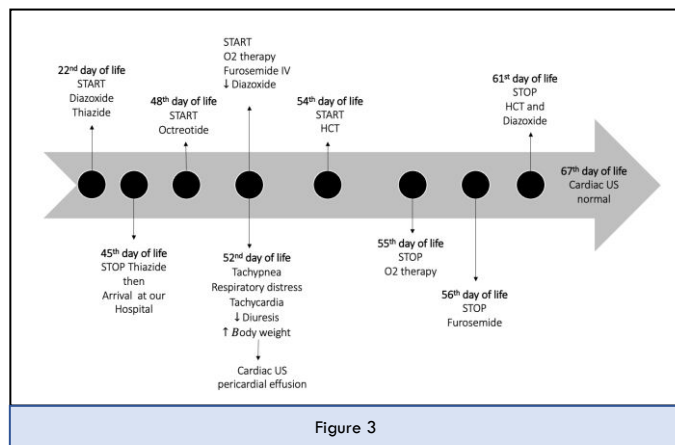

Figure 1

Figure 2

Figure 3

Subsequent cardiological evaluation with US showed pericardial effusion in the anterolateral site (0.5 - 0.7 cm), with no pulmonary hypertension signs, and left ventricular myocardial hypertrophy (Figure 2). In suspicion of an iatrogenic effect of diazoxide, after consultation with our pediatric anesthesiologist and cardiologist, therapy with IV furosemide was initiated. The diazoxide dosage was progressively reduced and subsequently suspended, while octreotide therapy was gradually increased. After three days, the patient's conditions improved, prompting the suspension of oxygen support. Furosemide was continued for five days, and hydrochlorothiazide was initiated on the third day, continuing for a total of eight days (Figure 3). During this time, the infant continued meals with formula integrated with maltodextrins via bottle and nasogastric tube. Daily monitoring by echocardiography revealed a progressive reduction of the pericardial effusion, culminating in complete resolution after 15 days from the onset of symptoms and four days after the complete suspension of diazoxide therapy. Once clinically stabilized, an 18Fluoro-DOPA PET/CT was performed to differentiate between a focal or diffuse form of CHI. The PET/CT highlighted the presence of a single focal accumulation

of the tracer located in the pancreatic tail, consistent with a focal form of hyperinsulinism. At the age of four months, the patient underwent a distal pancreatectomy with histological confirmation of a focal form of nesidioblastosis, resulting in a curative operation.

DISCUSSION

Diazoxide currently remains the only drug approved by the FDA for treatment of CHI [8]. However, over the last 50 years, severe adverse events (SAEs) related to diazoxide have been reported, including necrotizing enterocolitis [9], pericardial effusion [10-13], pulmonary hypertension, respiratory decompensation, congestive heart failure and death [14,15]. In 2015 FDA emphasized the risk of pulmonary hypertension in patients treated with diazoxide. Additionally, the FDA listed risk factors for this side effect [16]: various studies highlight that patients with a higher risk of cardiopulmonary diazoxide side effects include neonates with transient hyperinsulinism, premature neonates, neonates receiving high fluid rate infusion, neonates with sepsis, meconium aspiration syndrome, pneumonia, and congenital heart disease. Despite these risks, the effectiveness of diazoxide, coupled with a low overall number of SAEs [17], has led to a significant increase in its use over the years. Consequently, the rate of severe cardiorespiratory adverse events has risen from 5% to more than 16% [16,17].

The physiological effect of diazoxide is to bind to the SUR1 subunit of the KATP channels keeping them open and thereby inhibiting insulin secretion [18]. In addition, it also binds to the SUR2 subunit expressed in the cardiac muscle, smooth muscles, skeletal muscles and the brain. Due to its action on renal arterioles and renal tubular system, it also has antidiuretic and antihypertensive effects [19,20]. Thus, the off-target effects of diazoxide through its binding to the SUR2 subunit of the KATP channel may explain the most serious side effects (pulmonary hypertension, pericardial effusion and congestive heart failure) even though their physiopathology is not well defined: it remains unclear whether they are caused by primary damage to the cardiovascular system or by a secondary effect due to fluid retention. To reduce the risk of SAEs, the European society of Pediatric Endocrinology suggests performing a cardiopulmonary assessment (cardiac examination and US) in all infants before starting diazoxide and one week after the

beginning of the treatment, even if in the absence of signs of fluid overload [8,21]. They also strongly recommend starting thiazide diuretics at the same time of diazoxide due to risk of fluid retention and pulmonary hypertension [21]. Furthermore, fluid restriction before diazoxide treatment and routine surveillance during the treatment course are advised. These clinical practice guidelines for dosing and monitoring adverse events in infants treated with diazoxide can be highly useful for clinicians treating CHI patients. In line with these recommendations, it is crucial to discontinue the treatment promptly if a diazoxide-related side effect is suspected. Other previous publications describe different diazoxide collateral effects [22] such as hypertrichosis, bone marrow suppression (neutropenia and thrombocytopenia), hyperuricemia and gastrointestinal symptoms (poor appetite and vomiting). While these collateral effects are more frequent and well-known, they are generally considered minor and rarely require discontinuation of the drug.

When the patient was admitted to our centre, he was only taking diazoxide. At the age of 45 days, thiazide treatment was discontinued while diazoxide was continued. Before suspending thiazide, cardiac US was normal. We chose to continue diazoxide based on the baby's age and the normal cardiac ultrasound. After three days in our centre, we observed that the patient was diazoxide resistant and therefore octreotide was initiated (48 days of life). When the patient became symptomatic (at 52 days of life), he was transferred to NICU due to his serious clinical conditions. The patient was stabilized with HNFC and diuretic treatment. We conducted a comprehensive evaluation (blood tests and instrumental work-up) to understand the etiology of the acute symptoms. We considered the possibility of drug side effects and two factors made octreotide side effects more probable. Firstly, the timing of symptom onset: the patient had been taking diazoxide for over a month, while octreotide had only been initiated for 4 days. Additionally, the patient did not have any risk factors for diazoxide side effects, such as intravenous fluid administration, transient hyperinsulinism, abnormal cardiac ultrasound findings, or prematurity. The most serious octreotide side effect is NEC, which we ruled out through abdominal X-rays and observation over the following days. However, guidelines recommend immediately discontinuing diazoxide when cardiovascular side effects appear, even if the etiology of symptoms is unclear: it is advised to discontinue diazoxide promptly if the patient develops respiratory distress or fluid overload, while investigating other potential causes of the symptoms. Glycemic control should be managed without diazoxide. This case underscores the challenge of identifying diazoxide's cardiovascular effects, as each patient may present different confounding factors in their medical history (such as concomitant drugs or diseases, the presence or absence of risk factors, timing of symptom onset, etc.). It suggests considering diazoxide-related effects even when investigating other potential causes, and emphasizes that the diagnostic workup should not delay diazoxide discontinuation.

CONCLUSIONS

Diazoxide can be effective in treating CHI, but its use requires diuretic administration and careful surveillance to prevent and promptly diagnose potential life-threatening adverse effects. Although diazoxide cardiopulmonary side effects were previously described in sporadic case reports, the FDA has clearly listed them as SAEs since 2015. Despite this, numerous reports were published after the FDA statement, describing the increasing rate of these diazoxide side effects. Further studies are needed to identify the underlying mechanism and precise predisposing factors of diazoxide cardiopulmonary side effects. In current clinical practice, it is crucial to adhere to guidelines when initiating diazoxide, and if there is suspicion of cardiopulmonary side effects, the treatment should be promptly interrupted. Additionally, for patients with baseline comorbidities such as congenital heart disease or intolerance to diazoxide, alternative therapies for hyperinsulinism should be considered.

RIGHTS TO PRIVACY AND INFORMED CONSENT

The authors obtained informed consent from both caregivers for the publication of the images and clinical data contained herein.

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04

Diazoxide Toxicity in Congenital Hyperinsulinism: A Seldom-Considered Rare Side Effect. Annals of Diabetes, Metabolic Disorders & Control. 2024; 5(1):132.

SCIENTIFIC LITERATURE

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