CASE REPORT

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# Clinical and Genetic Characteristics and Outcome in Patients with Neonatal Diabetes Mellitus from a Low Middle-income Country

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### What is already known on this topic?

Neonatal diabetes mellitus (NDM) is a rare disorder where a genetic defect is identified in 80% of cases. The confirmation of these genetic defects plays a major role in further management and follow up of these patients.

### What this study adds?

This study reports a genetic diagnosis in 96% of the cases of NDM, investigated retrospectively, in a cohort of patients from Sri Lanka.

## Abstract

Neonatal diabetes mellitus (NDM) is a disorder characterized by persistent, severe hyperglycemia presenting during the first six months of life. These disorders are rare and the incidence is approximately 1 in 90,000 live births. The aim was to describe the clinical presentation, molecular genetics and outcome of patients with NDM from a single paediatric endocrine center from a low-middle income country, Sri Lanka. A retrospective study was conducted on patients diagnosed with NDM. Medical records were reviewed for demographic data and data on clinical, biochemical and genetic analysis. The majority (96%) who underwent mutation analysis had pathogenic genetic mutations on Sanger sequencing. Permanent NDM (PNDM) was diagnosed in 19 patients with three having a syndromic diagnosis. The most common mutation was in *KCNJ11*. The majority of patients with PNDM (63%) presented with severe diabetic ketoacidosis. All patients with Transient NDM remitted by six months of age. Nearly half (47%) with PNDM were switched to sulfonylurea therapy with good glycemic control (glycosylated haemoglobin A1c ranged 6-7.5%). Data from the Sri Lankan cohort is comparable with other populations. The majority of cases are due to *KCNJ11* mutations resulting in PNDM.

**Keywords:** Neonatal diabetes, genetics, clinical features, management, follow up

## Introduction

Neonatal diabetes mellitus (NDM) is a disorder characterized by persistent, severe hyperglycemia presenting during the first six months of life (1,2,3). It can infrequently present between the ages of six months to one year (1,2,4). NDM is rare with a reported incidence of 1 in 90,000 live births (1,2,4). According to the phenotypic characteristic of insulin requirement the cases of NDM can be categorized as transient (TNDM) or permanent (PNDM) (3,5). In up to 80% of the cases, a genetic mutation has been recorded (2,3). These mutations cause neonatal diabetes mellitus through three major pathophysiological processes: malformed pancreas with abnormal beta cells; functional alteration of insulin secreting cells causing abnormal insulin synthesis; and destruction of beta cells (1,2).

Anomalies of the 6q24 locus and mutations of the *ABCC8* and *KCNJ11* genes are frequent genetic causes of abnormal beta cell function (1). These defects and *UDP 6* mutation

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often cause TNDM (3,6). Mutations in *ABCC8* and *KCNJ11* are common in families without consanguinity (7). These mutations are also responsible for causing Maturity Onset Diabetes of the Young-MODY (7).

Genetic causes of PNDM remain obscure in most cases. In the non-consanguineous PNDM population, mutations in the ATP sensitive potassium channel and mutations in the *INS* gene are the most common finding, whereas in consanguineous families' mutations in the *INS*, *GCK* and *EIF2AK3* genes account for the majority of cases (3).

Studies on clinical and genetic characteristics of patients with NDM in South Asia are scarce. The diagnosis and genetic confirmation of these patients opens an avenue to a spectrum of management and follow up options (8). The aim of this study was to describe the clinical presentation, molecular genetics and long term follow up of a cohort of 24 patients with NDM from a single paediatric endocrine center in Sri Lanka.

## Case Report

### Study Design and Participants

#### Patients

An observational study of 24 registered cases of NDM presenting before one year of age were included.

#### Methods

Information collected from patients' records included demographic data (gender, age), clinical presentation, anthropometric measurements, laboratory findings at diagnosis, details on genetic analysis, treatment methods, comorbidities and adequacy of glycemic control on follow up. At diagnosis, the onset of diabetes mellitus and its complications were based on assessment of blood glucose levels, blood gases and electrolytes. Assessment of glycemic control was based on three monthly glycosylated haemoglobin A1c (HbA1c) levels. The values of HbA1c were categorized as good control (6-7.5%), fair control (7.51-9%), and poor control (>9%). Anthropometric measurements were taken by medical officers. Weight, height and body mass index were expressed as standard deviation scores according to the Centre for Disease Control and Prevention 2000 growth charts.

#### Genetic Analysis

Written, informed consent was taken from parents of patients who underwent genetic testing. Peripheral blood samples for genetic analysis were sent to University of Exeter Medical School, Exeter, United Kingdom. Genetic testing was undertaken for *ABCC8, KCNJ11, INS* and other mutations known to cause NDM. Analysis of the coding regions and exon/intron boundaries were done by targeted next generation sequencing. Sanger sequencing analysis and targeted next generation sequencing was used to confirm the genetic mutation in appropriate cases.

Patient no. 19 with trisomy 21 was found to have a recently recognised subtype of neonatal diabetes that is autoimmune but not human leukocyte antigen associated (Table 1). All other genetic causes were ruled out by sequencing and the NDM was found to be aetiologically caused by trisomy 21. Unfortunately, this patient was lost to follow up after eight months of age with the onset of the Covid pandemic. Therefore, this patient was not included in the study sample.

### Genetic Analysis

Of the 24 patients with NDM, 19 (79%) were diagnosed with PNDM and 5 (21%) had TNDM. Of the five patients with TNDM, three showed a 6q24 mutation. The remaining two TNDM patients showed mutations, one in the *ABCC8* gene and the other patient in the *INS* genes. The genetic mutations responsible for the cases of PNDM are illustrated in Figure 1.

Twenty fathers of the 24 NDM patients underwent genetic analysis, of whom 12 were unaffected, five were heterozygous and two showed non paternity. One father was affected and he is currently on sulfonylurea therapy with well-controlled diabetes (HbA1c 6.8).

### Clinical Presentation

Half of the 24 patients (50%) were female. and 12 (50%) were male. The age at presentation is shown in Figure

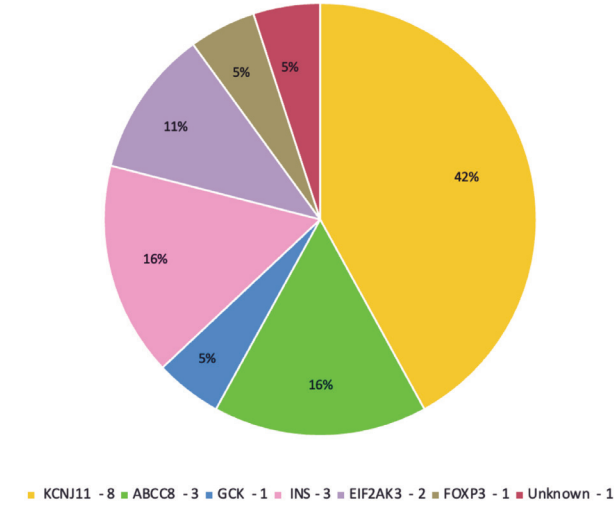


**Figure 1.** Genetic etiology of the patients with PNDM cohort
*PNDM: permanent neonatal diabetes mellitus*

2. A point of interest is that 4 out of the 5 patients with TNDM presented before four weeks of age. Furthermore, Patient 9 presented at 40 weeks and Patient 21 presented at 28 weeks. Both of these patients who presented after six months of age were positive for the *ABCC8* mutation.

Of the 19 patients with PNDM, 12 (63%) presented with severe diabetic ketoacidosis (DKA). Five of the 12 who presented with severe DKA were complicated with severe hypernatremia (serum sodium >170 mmol/L) and four patients suffered from stroke.

### Complications and Comorbidities

Patient 7 who presented with severe DKA and severe hypernatremia underwent amputation of the toes of the right lower limb due to thrombosis of the peripheral vessels. The initial peripheral cyanosis extended above the ankle. However, with low molecular weight heparin infusion the dry gangrene was confined to the toes which required amputation.

Patient 13 with the *EIF2AK3* mutation causing Wolkott Rallison syndrome has had three episodes of liver failure, genu valgum, scoliosis and atlanto occipital subluxation requiring fixation. Despite this, he succumbed to severe pneumonia at eight years of age.

Patient 14, also with Wolkott Rallison syndrome, is currently being followed up at the clinic with a mean HbA1c of 8%. However, he is severely disabled with kyphoscoliosis and is wheel chair bound.

Patient 15 with immune-mediated polyendocrinopathy and enteropathy X-linked (IPEX) syndrome caused by a *FOXP3* mutation, presented with nephrotic syndrome and alopecia and was found to have NDM at 11 months of age. He passed away at 2 years of age due to severe pneumonia and pleural effusion complicated by sepsis.

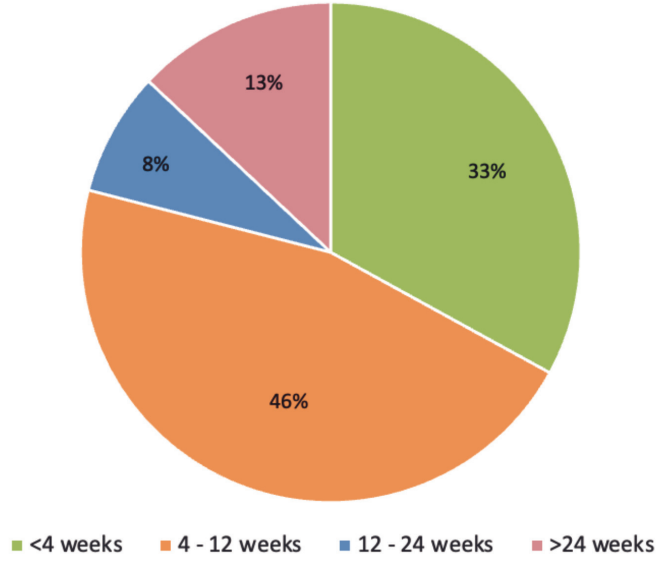


**Figure 2.** Age at presentation

### Follow-up

All patients with TNDM were weaned off drugs by six months of age with regular monitoring of HbA1c levels.

Eight patients (42%) with PNDM, including Patient 20 whose genetic etiology is unknown, are receiving insulin with fair glycemic control (mean HbA1c of 8%). The nine patients who made a successful switch to sulfonylureas have good glycemic control with mean HbA1c of 7.3%. These patients are being regularly followed up at the clinic in view of evaluation for development of complications of diabetes and assessment of growth and development.

Of the four patients who suffered from a stroke at presentation, two have exhibited delay in achieving age-appropriate developmental milestones.

All patients, apart from Patient 14 with Wolkott Rallison syndrome, are showing satisfactory weight and height gain.

## Discussion

In the past there have been a number of reports on clinical characteristics of NDM in European and Middle Eastern cohorts. To date there have been no published reports from Sri Lanka on comprehensive data on NDM, including genetic analysis. This is mainly because data on NDM, especially in view of long term follow up and genetic analysis is scarce. We present the clinical presentation, genetic analysis and glycemic control of patients with NDM from a single paediatric endocrine center in Sri Lanka.

### Genetic Analysis

In comparison to the percentage of patients with PNDM in the Israeli cohort (57%), the American cohort (70%) and the Indian cohort (50%), our cohort had a frequency of PNDM of 83%, which is markedly higher than in the other cohorts (2,3,9). The most common genetic etiology for PNDM was mutations in the *KCNJ11* gene (42%). This finding agrees with previous records of European and Middle eastern populations where mutations of the *ABCC8, KCNJ11* and *INS* genes were found to be the most frequent etiologies for PNDM (3,7).

Of the 19 patients with PNDM, three tested positive for genetic mutations consistent with syndromic forms of PNDM. Two were positive for the *EIF2AK3* mutation and one was positive for the *FOXP3* mutation. Mutations in transcription factors involved in embryological development

**Table 1. Results of genetic analysis and management of the neonatal diabetes mellitus cohort population**

| Patient no. | Status | Current management | Mutation | Maternal status | Paternal status |
|---|---|---|---|---|---|
| 1 | PNDM | Sulfonylurea therapy | Gene - *KCNJ11*<br>Zygosity - Heterozygous<br>HGVS description -NM_000525.3:c.602G > A p.(Arg201His)<br>Location: GRCh37 (hg19)<br>Chr11:g.17409037<br>Classification - Pathogenic | Unaffected | Affected |
| 2 | PNDM | Sulfonylurea therapy | Gene: *KCNJ11*<br>Location: Exon 1<br>DNA Description: c.149G > A<br>Protein Description: p.Arg50Gln (p.R50Q) Consequence: Missense | Unaffected | Unaffected |
| 3 | PNDM | Insulin | Gene: *KCNJ11*<br>Location: Exon 1<br>DNA Description: c.149G > C<br>Protein Description: p.Arg50Pro (p.R50P) Consequence: Missense | Unaffected | Unaffected |
| 4 | PNDM | Sulfonylurea therapy | Gene: *KCNJ11*<br>DNA Description: c.2972G > A<br>Protein Description: p.Ser991Asn (p.S991N) Consequence: Missense | Unaffected | Unaffected |
| 5 | PNDM | Sulfonylurea therapy | Gene: *KCNJ11*<br>Location: Exon 1<br>DNA Description: c.175G > A<br>Protein Description: p.Val59Met (p.V59M) Consequence: Missense | Unaffected | Unaffected |
| 6 | PNDM | Sulfonylurea therapy | Gene: *KCNJ11*<br>DNA Description: c.136C > T<br>Protein Description: p.(His46Tyr)<br>Consequence: Missense | Unaffected | Unaffected |
| 7 | PNDM | Sulfonylurea therapy | Gene: *KCNJ11*<br>Location: Exon 1<br>DNA Description: c.136C > T<br>Protein Description: p.(His46Tyr) Consequence: Missense | Unaffected | Unaffected |
| 8 | PNDM | Sulfonylurea therapy | Gene: *KCNJ11*<br>Zygosity - heterozygous<br>HGVS description -<br>NM_000525.3:c.175G > A.p(Val59Met)<br>Location - Chr11:g.17409464<br>Classification - pathogenic | Unaffected | Unaffected |
| 9 | PNDM | Sulfonylurea therapy | Gene - *ABCC8*<br>DNA Description: c.265C > T<br>Protein description: p.Arg89Cys (p.R89C)<br>Consequence: Missense | Heterozygous | Single mother |
| 10 | PNDM | Insulin therapy | Gene: *ABCC8*<br>Location: Exon 38<br>DNA Description: c.4568T > A<br>Protein Description: p.(Val1523Glu) Consequence: Missense | Affected | Heterozygous |
| 11 | PNDM | Sulfonylurea therapy | Gene - *ABCC8*<br>Zygosity - Heterozygous<br>Inheritance - Maternal<br>HGVS description - NM_001287174.1: c.970G > Ap.(Val324Met)<br>Location -Chr11:g.17482076C > T<br>Classification - Pathogenic | Heterozygous | Unaffected |
| 12 | PNDM | Insulin therapy | Gene: *GCK*<br>Location: Exon 5<br>DNA Description: c.562G > A<br>Protein Description: p.Ala188Thr (p.A188T) Consequence: Missense | Unaffected | Unaffected |
| 13 | PNDM | Deceased | Gene: *EIF2AK3*<br>Location: Exon 13<br>DNA Description: c.2588T > G<br>Protein Description: p.Leu863Ter (p.L863*) Consequence: Nonsense | Heterozygous | Non paternity |
| 14 | PNDM | Insulin therapy | Gene: *EIF2AK3*<br>Location: Exon 14<br>DNA Description: c.2972G > A<br>Protein Description: p.Ser991Asn (p.S991N) Consequence: Missense | Heterozygous | Heterozygous |

**Table 1. Continued**

| Patient no. | Status | Current management | Mutation | Maternal status | Paternal status |
|---|---|---|---|---|---|
| 15 | PNDM | Deceased | Gene: *FOXP3*<br>Location: Exon 12<br>DNA Description: c.1236G > C<br>Protein Description: p.Glu412Asp (p.E412D) Consequence: Missense | Heterozygous | Non paternity |
| 16 | PNDM | Insulin therapy | Gene: *INS*<br>Location: Exon 3<br>DNA Description: c.265C > T<br>Protein Description: p.Arg89Cys (p.R89C) Consequence: Missense | Unaffected | Unaffected |
| 17 | PNDM | Insulin therapy | Gene: *INS*<br>Location: Exon 3<br>DNA Description: c.265C > T<br>Protein Description: p.Arg89Cys (p.R89C) Consequence: Missense | Unaffected | Unaffected |
| 18 | PNDM | Insulin therapy | Gene - *INS*<br>DNA Description: c.149G > A<br>Protein Description: p.Arg50Gln (p.R50Q)<br>Consequence: Missense | Heterozygous | Heterozygous |
| 19 | PNDM | Lost to follow up | Where all other genetic causes have been ruled out by sequencing, neonatal diabetes in patients with Down syndrome is aetiologically caused by trisomy 21. This recently recognised subtype of neonatal diabetes is autoimmune but is not HLA associated. | Not checked | Not checked |
| 20 | PNDM | Insulin therapy | No mutation identified | Not checked | Not checked |
| 21 | TNDM | Off drugs | Gene: *ABCC8*<br>Location: Exon 8<br>DNA Description: c.1238C > G<br>Protein Description: p.Thr413Ser (p.T413S) Consequence: Missense | Heterozygous | Unaffected |
| 22 | TNDM | Off drugs | Gene - *INS*<br>Zygosity - Homozygous<br>Inheritance - Biparental<br>HGVS description - NM_001185098.1:c.-3<br>Location: GRCh37 (hg19)17A > C, p.?<br>Chr11:g.2182518<br>Classification - uncertain significance | Heterozygous | Heterozygous |
| 23 | TNDM | Off drugs | Partial hypomethylation at the TND locus. This finding is consistent with a diagnosis of TND caused by a duplication of *6q24* of paternal origin. | Not checked | Not checked |
| 24 | TNDM | Off drugs | Methylation specific MLPA - Loss of methylation of the PLAGL1 DMR<br>Dosage analysis - Normal dosage<br>Informative markers tested<br>- D6S1668 (6P25.1)<br>- D6S1721 (6p24.1)<br>- D65S1595 (6q15)<br>- D6S280 (6q13)<br>Maternal loss of heterozygosity for all<br>Interpretation -<br>MS-MLPA detected loss of methylation at the PLAGL1 DMR in the patients DNA sample.<br>Microsatellite analysis showed no maternal contribution for 4 polymorphic chromosome 6 markers.<br>The other 9 loci were not fully informative, but the patient was homozygous for all of them, consistent with uniparental disomy.<br>This result confirms a diagnosis of TND, very likely due to paternal uniparental disomy at the *624* locus. | Not checked | Not checked |
| 25 | TNDM | Off drugs | Gene - *ZFP57* resulting in hypomethylation at the maternal 6q24 locus.<br>Zygosity - Homozygous<br>Inheritance - Biparental<br>HGVS description -NM_001109809.2:c.844C > T<br>p.(Gln282*)<br>Location - Chr6:g.29641044<br>Classification - pathogenic | Heterozygous | Heterozygous |

PNDM: permanent neonatal diabetes mellitus, TNDM: transient neonatal diabetes mellitus, TND: transient neonatal diabetes, MS-MLPA: Methylation-Specific Multiplex Ligation-dependent Probe Amplification, DMR: differentially methylated region

of the pancreas and elevated endoplasmic reticular stress giving rise to destruction of beta cells are two mechanisms involved in the pathogenesis of NDM in syndromic forms. Mutations in the *EIF2AK3* gene are responsible for beta cell destruction due to increased endoplasmic reticulum stress whereas mutations in the *FOXP3* gene are responsible for immune mediated damage to beta cells (2).

Sixty percent of the cases with TNDM tested positive for mutations in 6q24 gene, which is in keeping with data from Middle Eastern (70%) and American cohorts. Mutations in the *ABCC8* and *KCNJ11* genes were the second most common causes of TNDM in these cohorts (2,3). However, in our cohort, the other cases of TNDM were found to be due to a mutation in the *INS* and *ABCC8* genes.

### Clinical Presentation

Cases of TNDM present earlier than PNDM (1,3,10). Moreover, patients with 6q24 mutation present earlier than those with potassium channel defects. This is evident in our cohort where 4 out of the 5 patients with TNDM presented before 4 weeks of age. However, the median age of presentation of cases with *KCNJ11* or *ABCC8* mutations was 9.6 weeks. However, presentation after six months of age has also been reported (2). Even in our cohort, two patients with *ABCC8* mutation and one patient with *KCNJ11* mutation presented after 6 months of age.

Presentation with DKA was more common in patients with PNDM when compared with cases of TNDM (10). Most (78.8%) of cases with mutations of *KCNJ11* or *ABCC8* presented with DKA whereas cases with TNDM due to overexpression of 6q24 did not present with DKA in the American cohort (2). This is evident in our cohort where none of the cases of TNDM presented with DKA. This is because the duration of insulinopenia is less in TNDM due to the earlier age of presentation (2) and the potassium channel mutations giving rise to PNDM cause a severe lack of insulin due to hyperpolarization of the membrane. This leads to marked reduction in insulin secretion whereas in TNDM there is only a reduction in beta cell function giving rise to a modest reduction in insulin secretion (3).

During the latter part of pregnancy insulin plays a major growth promoting role (6). Therefore, the lack of insulin leads to the low birth weight (1,3). All the patients in our cohort with K-ATP channel mutations had normal birthweight (birthweight > 2.5 kg).

Observation of growth parameters in our cohort revealed that all patients excluding Patient 14 with Wolkott Rallison syndrome showed satisfactory height and weight gain which may be attributed to proper glycemic control.

### Complications and Comorbidities

Patients 1 and 2 with PNDM had a severe course complicated with DKA, hypernatremia and stroke. Fortunately, they are currently achieving age appropriate developmental milestones. They are on sulfonylureas therapy with good glycemic control (mean HbA1c 7%) (11).

Patients 3 and 12 also had a severe course complicated with severe DKA and stroke. However, their course was further convoluted with developmental delay and they are currently receiving multi-disciplinary care. They have a fairly controlled diabetes with a mean HbA1c of 8.5% (11).

The remaining 20 patients have no concerns regarding achievement of age-appropriate developmental milestones.

### Follow-up

Successful treatment with sulfonylureas has been achieved in patients with *ABCC8* and *KCNJ11* mutations (1,2,3). The *KCNJ11* and *ABCC8* genes code for the Kir6.2 subunit and the SUR 1 ion-channel regulator subunit of the K-ATP channel respectively[4]. Sulphonylureas act on the K-ATP channel to induce closure of the channels, thus causing release of insulin from beta cells (6). Management with sulphonylureas has the advantages of reducing the incidence of hypoglycemia and improving the neurological and visual impairment in patients, if introduced early (1,12). The most frequently used sulphonyurea in NDM is glibenclamide (2). Nine out of the 12 patients with *ABCC8* or *KCNJ11* mutations in our cohort are currently on glibenclamide with a good glycemic control (mean HbA1c 7.3%) (11).

Eight patients with PNDM are currently on insulin administered according to the multiple daily dose regime. Initial management while the patient is on milk feeds is with long acting insulin agents. With the introduction of complimentary food, short acting insulin therapy prior to meals is initiated. It should be noted that due to financial and socio-economic constraints none of our patients are on insulin pumps. Furthermore, capillary sugars are checked using auto lancets as the luxury of continuous glucose monitors are not financially feasible in Sri Lanka. Glycemic control in this cohort is fair with mean HbA1c of 8%.

As this study was conducted in a single center in Sri Lanka the true incidence rate of NDM across the country cannot be estimated.

## Conclusion

Data from our cohort is comparable with other populations. PNDM accounts for majority of the cases with mutations of

the *KCNJ11* responsible for a higher percentage of the cases. TNDM presents at an earlier age and remits by six months of age. The proportion of patients with PNDM presenting with severe DKA is higher than in patients with TNDM. Patients with *ABCC8* and *KCNJ11* mutation more frequently make a successful switch to sulfonylurea therapy.

A diagnosis of NDM should be considered in neonates and infants with persistent refractory hyperglycaemia. Genetic testing should be considered, as knowledge regarding the specific causative genetic mutation can appreciably modify the course of treatment. Close follow up is required in all patients with NDM in view of screening for complications and assessment of growth and development.

### Ethics

**Informed Consent:** Written, informed consent was taken from parents of patients who underwent genetic testing.

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### Footnotes

### Authorship Contributions

Concept: Navoda Atapattu, Ishara Minuri Kumarasiri, Design: Navoda Atapattu, Ishara Minuri Kumarasiri, Thabitha Jebaseeli Hoole, Imalka Jayasundara, Data Collection or Processing: Navoda Atapattu, Ishara Minuri Kumarasiri, Reha Balasubramaniam, Manimel Wadu Akila Nimanthi, Analysis or Interpretation: Navoda Atapattu, Ishara Minuri Kumarasiri, Literature Search: Navoda Atapattu, Ishara Minuri Kumarasiri, Thabitha Jebaseeli Hoole, Imalka Jayasundara, Reha Balasubramaniam, Manimel Wadu Akila Nimanthi, Writing: Navoda Atapattu, Ishara Minuri Kumarasiri.

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## References

1. Beltrand J, Busiah K, Vaivre-Douret L, Fauret AL, Berdugo M, Cavé H, Polak M. Neonatal Diabetes Mellitus. Front Pediatr. 2020;8:540718.
2. Dahl A, Kumar S. Recent Advances in Neonatal Diabetes. Diabetes Metab Syndr Obes. 2020;13:355-364.
3. Mouler M, Lebenthal Y, de Vries L, Yackobovitch-Gavan M, Averbuch NS, Fauret-Amsellem AL, Cavé H, Beltrand J, Polak M, Phillip M, Nimri R. Clinical characteristics, growth patterns, and long-term diabetes complications of 24 patients with neonatal diabetes mellitus: A single center experience. Pediatr Diabetes. 2022;23:45-54. Epub 2021 Dec 6
4. Lemelman MB, Letourneau L, Greeley SAW. Neonatal Diabetes Mellitus: An Update on Diagnosis and Management. Clin Perinatol. 2018;45:41-59. Epub 2017 Dec 16
5. Costa-Riquetto AD, de Santana LS, Franco PC, Jr ACS, Martio AE, Lisboa HRK, Kohara SK, Teles MG. Genetic and clinical features of neonatal and early onset diabetes mellitus in a tertiary center cohort in Brazil. Clin Genet. 2023;103:434-447. Epub 2022 Dec 23
6. Aguilar-Bryan L, Bryan J. Neonatal diabetes mellitus. Endocr Rev. 2008;29:265-291.
7. Warncke K, Eckert A, Kapellen T, Kummer S, Raile K, Dunstheimer D, Grulich-Henn J, Woelfle J, Wenzel S, Hofer SE, Dost A, Holl RW. Clinical presentation and long-term outcome of patients with KCNJ11/ABCC8 variants: Neonatal diabetes or MODY in the DPV registry from Germany and Austria. Pediatr Diabetes. 2022;23:999-1008. Epub 2022 Jul 23
8. Nyangabyaki-Twesigye C, Muhame MR, Bahendeka S. Permanent neonatal diabetes mellitus - a case report of a rare cause of diabetes mellitus in East Africa. Afr Health Sci. 2015;15:1339-1341.
9. Ganesh R, Suresh N, Vasanthi T, Ravikumar KG. Neonatal Diabetes: A Case Series. Indian Pediatr. 2017;54:33-36. Epub 2016 Nov 5
10. Polak M, Cavé H. Neonatal diabetes mellitus: a disease linked to multiple mechanisms. Orphanet J Rare Dis. 2007;2:12.
11. Kavthekar SO, Mali VT, Verma S, Kurane AB, Patil NB, Kulkarni SP. Evaluation of Microalbuminuria and Glycosylated Hemoglobin in the Assessment of Diabetes Control in Children with Type 1 Diabetes Mellitus Hospitalized with Diabetic Ketoacidosis. J Compr Ped. 2021;12:e109904.
12. Wu B, Xu W. Case report: Neonatal diabetes mellitus caused by KCNJ11 mutation presenting with intracranial hemorrhage. Front Neurol. 2013;14:1072078.