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The Effect of High-dose Methylprednisolone on HbA1c, HOMA-IR, Fasting Glucose and Lipid Profile in Child Patients with Lupus Nephritis

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Abstract: - High-dose methylprednisolone (MP) is widely used to treat aggressive Lupus Nephritis (LN), which may cause metabolic disturbances. Yet, the research on this issue is still controversial. This study aims to analyze the effect of high-dose methylprednisolone on fasting glucose, HbA1c, Homeostatic Model Assessment for Insulin Resistance (HOMA-IR), total cholesterol, and LDL in children with lupus nephritis. An observational analytical study with a prospective approach was conducted from June to August 2021. The study sample was lupus nephritis patients at the Pediatric ward of Dr. Soetomo Hospital who met the inclusion and exclusion criteria. The metabolic components (fasting glucose, total cholesterol, HDL, LDL, TG and HOMA-IR) were measured on day 1 before and day-4 after three days of high-dose MP treatment. The comparative test used is the paired t-test and the Mann-Whitney test. Thirty patients were recruited, 16 were girls, with a mean age was 14.15 years old. Most patients (16.7%) were in the fourth cycle of high-dose MP treatment. The mean BMI value in male subjects was 19.79 and that in female subjects was 19.12. We identified significant differences before and after high dose MP in mean fasting glucose (78.17 vs. 110.10, respectively; p=0.001), mean HOMA-IR (3.13 vs. 4.55; p=0.001), mean LDL (132.12 vs. 157.00; p=0.001), mean total cholesterol (202.37 vs. 235.10; p=0.001), mean systole (107.33 vs. 112.33; p=0.005), mean diastole (70.00 vs. 74.50; p=0.002). The comparison of mean not significant result in mean TG values (p>0.05). There was a significant increase in blood sugar levels, HOMA-IR, total cholesterol, and LDL after administration of high-dose methylprednisolone therapy.

Key Words: —*Methylprednisolone megadose, Lupus nephritis, Lipid profile.*

I. INTRODUCTION

Lupus nephritis (LN) is one of the most serious manifestations of the autoimmune disease Systemic Lupus Erythematosus (SLE) (Almaani et al., 2017) and 80% of SLE cases in children develop into LN. (Liu & Davidson, 2012) Immunosuppressants are currently the main therapy recommended starting early in LN patients to prevent irreversible kidney damage and life-threatening complications. (Tunnicliffe et al., 2018).

Based on the Clinical Practice Guidelines (PPK) RSUD Dr. Soetomo in 2017, LN management was divided into two phases, namely the induction phase and the maintenance phase.

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The induction phase uses high-dose methylprednisolone given intravenously at a dose of 10-30 mg/kg body weight for three (3) days, followed by a maintenance phase with prednisone or oral prednisolone starting at a dose of 0.5-1 mg/kg/day (maximum 30 days) mg) every day.(SMF Department Ilmu Kesehatan Anak, 2017) Administration of high-dose corticosteroids such as high-dose methylprednisolone is effective in reducing morbidity and mortality in LN due to the effect of glucocorticoids on the innate and adaptive immune system and has a rapid onset of action.(Chatham & Kimberly, 2001) However, high doses of corticosteroids can cause side effects related to therapeutic doses and long-term use, such as disruption of metabolic components in the body.(Hernandez-Baixauli et al., 2020).

Disruption of metabolic components in LN patients receiving high-dose methylprednisolone therapy can include hyperglycemia, insulin resistance, central obesity, hypertension and dyslipidemia which will increase the risk of atherosclerotic cardiovascular disease (CVD).(Grundy, 2004) Several cases of foreign patients receiving high-dose methylprednisolone

therapy at the Inpatient Inpatient Unit (IRNA) of the nephrology division of RSUD Dr. Soetomo Surabaya showed an increase in blood sugar levels before and after therapy. However, research on changes in metabolic profile related to side effects of high-dose methylprednisolone therapy in pediatric patients with lupus nephritis has never been conducted at dr.Soetomo Hospital Surabaya. Based on this, it is necessary to conduct a study evaluating changes in the metabolic profile of children with LN receiving high doses of methylprednisolone.

II. METHODS

This study is an analytical observational study with a prospective approach. This study was granted ethical approval by the Ethics Committee of Dr. Soetomo General Academic Hospital No. 0202/KEPK/V/2021 dated May 31, 2021. The inclusion criteria in this study were children aged 18 years who were diagnosed with lupus nephritis; children with lupus nephritis who received high-dose methylprednisolone therapy for 3 days; and parents/guardians agree to participate in the study as evidenced by signing the informed consent and having been given information for consent. Exclusion criteria in this study were children with lupus nephritis whose diagnosis changed during the study to abnormalities outside the kidney; the patient has delayed methylprednisolone therapy or is not receiving the full dose; the parent/guardian withdraws or withdraws from the research participation; patients died during the study before the evaluation was completed, and children with a history of glucose metabolism disorders such as diabetes mellitus before pulse methylprednisolone therapy were given.

Samples were taken by consecutive non-random sampling. The minimum number of samples required is 26 children, which is calculated based on the one unpaired group formula with pre-post-study measurements. The study was conducted by recording the results of fasting blood sugar, fasting insulin, fasting lipid profiles and HbA1c in pediatric patients with lupus nephritis before and after high-dose methylprednisolone therapy who were treated in the Nephrology Room, Pediatric Inpatient Unit (IRNA), Department of Pediatrics. , RSUD dr. Soetomo Surabaya. Laboratory examinations were carried out at the Clinical Pathology Laboratory, Diagnosis Center Building, RSUD dr. Soetomo, Surabaya. Observations were made twice, namely before the administration of high-dose methylprednisolone therapy on the first day and the fourth day after pulse methylprednisolone therapy (t = 0), and the day (t = 1).

Data were entered in the Statistical Software Program for Social Science (SPSS). Data analysis was conducted using a comparative hypothesis test, to determine whether there was a difference between cortisol levels before and after high-dose methylprednisolone therapy. The comparative test used is the paired t-test if the data is normally distributed ($p > 0.05$) or the Wilcoxon test if the data is not normally distributed ($p < 0.05$). A comparative test of metabolic profile values or levels between metabolic and non-metabolic syndrome groups using an unpaired t-test if the data is normally distributed ($p>0.05$) or the Mann-Whitney test if the data is not normally distributed ($p<0.05$). The relationship between changes in the value or level of the metabolic profile and the incidence of metabolic syndrome using the Spearman test. The results of statistical tests are said to be significant if $p < 0.05$ with a 95% confidence interval.

III. RESULTS

In this study, female subjects were found to be more dominant than men. The age range of the research subjects was 2-17 years with an average age of 14.15 ± 3.33 years. Subjects are lupus nephritis patients who have received methylprednisolone therapy and, in this study, dominated by patients receiving methylprednisolone in the 4th cycle. The unpaired t-test showed that there was no significant difference in all anthropometric data for both women and men ($p>0.05$) (data not shown). The average HbA1c level of all research subjects was 5.39 mg/dl with a standard deviation of ± 0.58. Of all subjects, 5 patients had elevated HbA1c levels.

Table.1. Subjects' characteristics

Characteristics	n (%)
Sex	
• Male	14 (47)
• Female	16 (53)
Age	
• < 6 years old	1 (3.3)
• 6-12 years old	4 (13.3)
• >12 years old	25 (83.3)

MP therapy cycle	
• 1st	3 (10)
• 2nd	7 (23.3)
• 3rd	2 (6.7)
• 4th	11 (36.7)
• 5th	4 (13.3)
• 6th	3 (10)
BMI	
• Underweight	15 (50)
• Normal	10 (33.3)
• Overweight	5 (16.7)
• Obesity	0 (0)
HbA1c	
• Normal	25 (83.3)
• Pre-diabetes	3 (10)
• Diabetes	2 (6.7)

Table.2. Effects of MP therapy on the metabolic components

Variables	Mean		p
	Before MP therapy	After MP therapy	
Fasting Glucose	78.17±16.98	110.10±16.75	0.001*
HOMA-IR	3.13±2.02	4.55±2.17	0.001*
LDL	126.90±59.05	157.00±69.33	0.001*
HDL	52.70±17.26	58.60±16.84	0.077*
Total Cholesterol	202.37±77.06	235.10±88.15	0.001*
Triglyceride	160.27±89.22	151.17±92.91	0.430*
Hypertension (n)	3	7	0.041**

All variables show significant results except triglyceride.
* Wilcoxon test
** Chi-square test

In this study, most of the subjects experienced an increase in HOMA-IR values after methylprednisolone therapy (83.3%). However, as many as 5 subjects (16.6%) had higher HOMA-IR values before treatment than after therapy.
A total of 15 subjects (50%) had lower post-therapy triglyceride values than before treatment, 14 patients (46.67%) had higher post-treatment triglyceride values and only 1 patient had the same post- and pre-treatment triglyceride values.
Most of the lupus nephritis patients (25 patients or 83.33%) experienced an increase in HDL values after being given therapy and there were only 5 patients who had higher HDL values before treatment than after therapy.
A total of 26 subjects (86.6%) experienced an increase in fasting blood sugar after therapy and only 4 subjects (13.33%) experienced a decrease in fasting blood sugar after therapy.
Table 3 describes the differences in the values of the variables observed before and after methylprednisolone therapy based on cycles of therapy less than 4 and more than 4. There were changes in fasting blood sugar levels, HOMA-IR, total cholesterol, HDL, and TG after therapy in the cycle group. less than 4 and statistically significant ($p<0.05$). The results of the analysis showed that there were significant differences between HDL and LDL variables before and after therapy ($p<0.05$).

Table.3. Differences in the value of the metabolic profile of study subjects before and after high-dose methylprednisolone therapy in the therapy cycle group of less than 4.

Cycle <4	Pre	Post	*P-value*
Fasting Blood Glucose			
Normal, n(%)	12	9	-
Abnormal, n(%)	0	3	
HOMA-IR			0,014*
Normal, n(%)	8	6	
Abnormal, n(%)	4	6	
Cholesterol			0,018*
Normal, n(%)	5	3	
Abnormal, n(%)	7	9	
Triglyceride			0,679
Normal, n(%)	7	8	
Abnormal, n(%)	5	4	
HDL			0,046*
Normal, n(%)	6	9	
Abnormal, n(%)	6	3	
LDL			0,067
Normal, n(%)	5	2	
Abnormal, n(%)	7	10	
HbA1c			
Normal, n(%)	10		

Abnormal, n(%)	2		

* chi-square test

Table.4. The difference in the value/level of the metabolic profile of the study subjects before and after high-dose methylprednisolone therapy in the group of therapy cycles of more than 4.

Cycle >4	Pre	Post	*P-value*
Fasting Blood Glucose			-
Normal, n(%)	18	17	
Abnormal, n(%)	0	1	
HOMA-IR			0,180
Normal, n(%)	12	10	
Abnormal, n(%)	6	8	
Cholesterol			0,002*
Normal, n(%)	11	8	
Abnormal, n(%)	7	10	
Triglyceride			0,168
Normal, n(%)	10	10	
Abnormal, n(%)	8	8	
HDL			-
Normal, n(%)	12	18	
Abnormal, n(%)	6	0	
LDL			0,002*
Normal, n(%)	10	7	
Abnormal, n(%)	8	11	
HbA1c			
Normal, n(%)	15		
Abnormal, n(%)	3		

* chi-square test

IV. Discussion

4.1 Basic Characteristics of Research Subjects

In this study, female research subjects were more dominant than males (53% and 47%). This is consistent with the prevalence of lupus nephritis in children. The reference states that the incidence of lupus nephritis in children is more common in women with a ratio of 4.7-5.9:1.(Bogdanovíc et al., 2004) A study states that the frequency of SLE is greater in women than men due to differences in the metabolism of sex hormones and/or GnRH hormones (Gonadotropin-Releasing hormone).(Yacoub Wasef, 2004) Estrogen hormones can cause effects through their receptors, namely alpha and beta estrogen receptors (ER-/β) which are found on immune cells such as thymus cells, bone marrow cells, T cells, B cells, and dendritic cells. Estrogen can stimulate autoreactive B cells, causing a failure of the immune response and autoantibody secretion.(Morris & Putterman, 2012; Shoenfeld et al., 2012) In addition, the number of X chromosomes is said to be associated with the risk of developing SLE.(Weckerle & Niewold, 2011) On the other hand, according to another study, complications of SLE in the form of lupus nephritis are more common in men.(Hsu et al., 2011) An American study showed that the progression of nephritis in lupus patients was more rapid in male patients than in female patients.(Seligman et al., 2002)

In this study, most (83%) patients were in the age range of 12 to 18 years, this finding is similar to several references which state that the diagnosis of lupus in pediatrics mostly occurs in the age range of 14 to 20 years.(Mina & Brunner, 2010; Wenderfer et al., 2016) Another study stated that the onset of lupus on average occurs in children aged 11 and 12 years, and rarely occurs in children younger than 5 years.(Sinha & Raut, 2014).

Glucocorticoids stimulate adipocyte differentiation, triggering adipogenesis through transcriptional activation of differentiation genes including lipoprotein lipase, glycerol-3-phosphate dehydrogenase and leptin. Long-term effects of high glucocorticoid levels can stimulate visceral or central adipose.(Kadmiel & Cidlowski, 2013) In addition, glucocorticoids affect carbohydrate metabolism by increasing gluconeogenesis and storing glucose for use by essential tissues such as the brain and red blood cells and reducing use in non-essential tissues such as muscle.(Gupta & Bhatia, 2008).

In this study, most patients were on the 4th cycle of high-dose methylprednisolone therapy (36.7%). In addition, the patient had a mixed history of prednisone use. The history of prednisone use is the cumulative dose of prednisone the patient received in the previous cycle.

LN therapy is divided into two stages, namely induction therapy and maintenance therapy.(Arici et al., 2015) LN therapy regimen in the induction phase is high dose intravenous methylprednisolone every 2-4 weeks at a dose of 10-30 mg/kg/day (maximum 1 gram) for 3 days for 6 cycles, followed by oral prednisone therapy starting at a dose of 0.5- 1 mg/kg/day (maximum 30 mg) daily, and decreased gradually by 5 mg/day within one month after high-dose methylprednisolone and depending on disease activity.

Glucocorticoids have an anti-inflammatory and immunosuppressant activity that acts on lymphocytes and inflammatory cells through inhibition of the NF-B transcriptional pathway. Therefore, glucocorticoids are effective drugs for the treatment of various manifestations of SLE.(Chatham & Kimberly, 2001) High-dose methylprednisolone therapy can suppress circulating monocytes and lymphocytes (mainly T lymphocytes).(Parker & Bruce, 2007).

4.2 Metabolic Profile Before and After Methylprednisolone Megadose Therapy

In this study, patients with lupus nephritis were evaluated for fasting glucose levels, HOMA-IR, lipid profile (total cholesterol, triglycerides, HDL and LDL) and blood pressure before and after high-dose methylprednisolone therapy. In addition, all patients were evaluated for HbA1c levels.

Disruption of metabolic components in LN patients receiving high-dose methylprednisolone therapy can include hyperglycemia, insulin resistance, central obesity, hypertension and dyslipidemia which will increase the risk of atherosclerotic cardiovascular disease (CVD).(Grundy, 2004).

In this study, laboratory data in the form of fasting blood sugar (GDP) increased after administration of high-dose methylprednisolone therapy in 26 subjects. The Wilcoxon test analysis showed a significant difference in fasting blood sugar values before and after high-dose methylprednisolone therapy (p=0.001).

This is in accordance with several references which state that glucocorticoids can cause insulin resistance and increased blood sugar levels with protein and fat catabolism. A study found that 12.6% of SLE patients who received high-dose glucocorticoid therapy experienced glucocorticoid-induced diabetes (GDM). They mentioned that the factors that influence the incidence of GDM are age, family history of diabetes mellitus, glucocorticoid dose and use of MMF.(Ha et al., 2011) The pathophysiology of steroid-associated hyperglycemia is usually initiated by insulin resistance due to skeletal muscle loss through protein breakdown, increased intracellular lipids and circulating free fatty acids that interfere with glucose utilization.(Rochlani et al., 2017) Steroids interfere with insulin signalling through direct effects on insulin receptors and glucose transporters as well as peroxisome proliferator-activated pathways. Steroids also increase gluconeogenesis through liver stimulation and by increasing insulin resistance because insulin is a major suppressor of hepatic glucose production.(Rask-Madsen & Kahn, 2012) Steroids not only exacerbate hyperglycemia in diabetes mellitus (DM) but also cause DM without a history of hyperglycemia, with an incidence that can reach up to 46% of patients, and an increase in glucose levels of up to 68% compared to baseline.(Ginsberg et al., 2005).

In this study, there was an increase in HOMA IR after high-dose methylprednisolone therapy (88.5%). However, some subjects (16.6%) had higher HOMA-IR values before treatment than after treatment. A total of 15 subjects (50%) had lower post-therapy triglyceride values than before treatment, 14 patients (46.67%) had higher post-treatment triglyceride values and only 1 patient had the same post- and pre-treatment triglyceride values. The results of the examination of HDL values in this study showed an increase in HDL values after high-dose methylprednisolone therapy. Almost all lupus nephritis patients (25 patients or 83.33%) experienced an increase in HDL values after treatment and there were only 5 patients who had higher HDL values before treatment than after therapy.

In further analysis, there was a significant increase in blood sugar levels, HOMA IR, total cholesterol, and LDL after high-dose methylprednisolone therapy (p=0.001). Another analysis showed that there was an increase in HDL levels and a decrease in triglycerides after high-dose methylprednisolone therapy, but this was not statistically significant.

A 2018 study stated that SLE patients had higher cholesterol levels, especially LDL.(Mobini et al., 2018) Another study stated that 30% of SLE patients had elevated LDL levels, and 11.8% had hypercholesterolemia.(Sinicato et al., 2017).

Dyslipidemia, hyperglycemia and hypertension are the most significant cardiovascular side effects of glucocorticoid therapy. However, the full mechanism is not yet fully understood. Changes in human lipid profile at various doses of prednisone have been reported in several studies, including an increase in VLDL, TG and LDL cholesterol, as well as an increase or decrease in HDL cholesterol. The pathogenetic mechanisms are multifactorial, including direct and indirect effects of cortisol on lipolysis, production-regulation of free fatty acids, VLDL synthesis and fat accumulation in the liver. AMP-activated protein kinase mediates many of the metabolic changes induced by glucocorticoids. Insulin resistance plays a key role in determining lipid abnormalities. Other hormonal changes involved include growth hormone, testosterone in men and estrogen in women, catecholamines and cytokines. In vitro, cortisol increases lipoprotein lipase in adipose tissue and especially in visceral fat where lipolysis is activated, resulting in the release of free fatty acids into the circulation. Increased

free fatty acids can increase hepatic lipid accumulation which will reduce glucose intake and activate various serine kinases resulting in decreased insulin signaling.(Arnaldi et al., 2010)

In this study, there was a significant increase in the incidence of hypertension after high-dose methylprednisolone therapy. Administration of glucocorticoid therapy is associated with an increased risk of hypertension and this relationship is dose-related. However, scientific evidence is inconsistent, and the pathophysiology of glucocorticoid-induced hypertension is unclear.(Mebrahtu et al., 2020) A study in 2015 noted that systemic exposure to synthetic glucocorticoids was not associated with clinically significant changes in blood pressure during the first three months of exposure, either in persons prescribed antihypertensive drugs or in those not exposed to these medications before glucocorticoid exposure. However, prednisone/prednisolone is associated with a higher risk of elevated blood pressure than other synthetic glucocorticoids.(Fardet et al., 2015).

Endogenous glucocorticoids are known to increase blood pressure, but very little is known about the initial effects of synthetic glucocorticoids.(Fardet et al., 2015) Glucocorticoids cause hypertension through several mechanisms: their intrinsic mineralocorticoid activity; through activation of the renin-angiotensin system; increasing vasoactive substances, and causing suppression of the vasodilatory system. In addition, glucocorticoids may exert some hypertensive effects on cardiovascular regulation via the CNS via glucocorticoid and mineralocorticoid receptors.(Cicala & Mantero, 2010)

4.3 The incidence of metabolic syndrome in pediatric patients with lupus nephritis receiving high-dose methylprednisolone therapy

In this study, there were 5 (16.6%) of all subjects had metabolic syndrome after being given high-dose methylprednisolone therapy according to the criteria used (NCEP ATP III).

These results are similar to the findings of an Australian study with a 5-year follow-up (2007-2015), the incidence of metabolic syndrome was identified in 29% of patients with SLE. Four out of five patients had at least one component of the metabolic syndrome in which the most commonly observed significant comorbid burden in SLE patients was arterial hypertension, followed by dyslipidemia, hyperglycemia, and obesity.(Gupta & Bhatia, 2008).

In 2017, a study was conducted on 76 SLE patients aged adolescents-young adults with an average age of 16.7 ± 4 years. They found that 13 patients had metabolic syndrome (18.4%). They also mentioned that the prevalence of metabolic syndrome in SLE patients aged <18 years was significantly higher than in those aged 18 years.(Sinicato et al., 2017).

Some patients with lupus nephritis have an increased risk of developing metabolic disease. Metabolic syndrome is a chronic proinflammatory and prothrombotic state associated with an increased risk of atherosclerosis, cardiovascular events and type 2 diabetes. HDL) and insulin resistance.(Alberti et al., 2009).

While the pathophysiology of the metabolic syndrome is complex and still not fully understood, the most commonly used theory is that a low-grade chronic inflammatory state occurs as a result of visceral adiposity, through the release of proinflammatory cytokines by adipocytes, proinflammatory adipokines including resistin, tumor necrosis factor (TNF), interleukins. (IL)-1, IL-6, monocyte chemoattractant protein-1 (MCP-1), lipocalin-2 and plasminogen activator inhibitor-1 (PAI-1) combine to mediate effects including increased insulin resistance, thereby increasing glucose and lipid levels. free. The imbalance between proinflammatory and anti-inflammatory adipokines in the regulation of the metabolic syndrome leads to an overall increase in inflammation, endothelial dysfunction and oxidative stress. This causes accelerated atherosclerosis, cardiovascular events and death.(Gupta & Bhatia, 2008).

Glucocorticoids cause insulin resistance throughout the body through visceral adipogenesis, mobilization, and release of free fatty acids into the circulation and the development of hepatic steatosis. In addition, hyperglycemia results from cellular dysfunction decreased insulin secretion and increased gluconeogenesis. In skeletal muscle, glucocorticoids cause type II fibre atrophy and decreased glucose intake. Bone loss occurs due to an increase in bone resorption followed by a decrease in the formation of a decrease in the function and number of osteoblasts.(Opata et al., 2016).

In this study, there were significant differences in the mean values of fasting blood sugar, HDL, and post-therapy triglycerides between groups of patients with and without metabolic syndrome. Patients with metabolic syndrome are a group at high risk of cardiovascular disease, they show several abnormalities in the lipid profile in addition to an increase in LDL, namely an increase in triglyceride, cholesterol and LDL levels, and a decrease in HDL.(Alberti et al., 2009).

In this study, there is a relationship between changes in the average value of changes in metabolic components after and before therapy with the incidence of metabolic syndrome. The highest and most significant average change after and before therapy is in fasting blood sugar parameters. Another parameter that also shows a significant change and relationship with the incidence of metabolic syndrome is HDL. However, in this

study, there was no significant relationship between the amount of MP therapy and the incidence of metabolic syndrome.

In line with the results of this study, a study in 2008 showed that long-term glucocorticoid exposure was not associated with a higher prevalence of metabolic syndrome in patients with rheumatoid arthritis.(Toms et al., 2008) In contrast, another study suggested that the use of local corticosteroids, especially the inhaled type, as well as systemic corticosteroids was associated with a higher likelihood of having the metabolic syndrome, higher BMI, and other adverse cardiometabolic risks, especially in women.(Savas et al., 2017).

The results of this study indicate that the administration of high doses of MP can worsen the metabolic profile as hypothesized in this study. Several confounding factors other than the basic characteristics of the subject such as cycle therapy, maintenance phase steroid therapy and stress factors are difficult to evaluate. It is necessary to monitor the side effects of the use of MP related to blood sugar, insulin resistance, lipid profile and blood pressure to see the metabolic profile for three consecutive days of high-dose MP therapy, for six cycles continuously. So that it is expected to be able to provide a better prediction of the incidence of metabolic syndrome in lupus nephritis patients, especially those who are receiving high-dose methylprednisolone therapy considering that patients with lupus nephritis are burdened with high morbidity factors to accelerate the occurrence of atherosclerosis, cardiovascular disease and increased mortality.

V. Conclusion

In this study, there was a significant increase in fasting blood sugar, HOMA-IR, and cholesterol and LDL levels in children with lupus nephritis after high-dose methylprednisolone therapy. Five patients experienced an increase in HbA1c levels, 3 patients were included in the prediabetes category and the remaining 2 were in the diabetes category. However, this research has its limitation which is a small number of subjects and a short duration of research. Thus, further research is needed on changes in the metabolic profile in lupus nephritis patients receiving high-dose methylprednisolone therapy with more subjects and longer study duration.

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