Glycemic Control Could Reverse Subclinical Atherosclerotic Changes and Normal Adiponectin Levels in Lean Type-1 Diabetic Children

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H. A. Atwa, H. Shora

Diabetes mellitus type 1 (DM1) is a known risk factor for arterial atherosclerosis. Individuals with DM1 have a 2-4 times higher risk of developing atherosclerotic diseases [1]. The pathogenesis of this increased risk for premature heart disease in DM1 is enigmatic. Atherosclerosis is regarded as an inflammatory disease. Many studies have established adipose tissue as an endocrine organ capable of hormone and cytokine production [2]. It was discovered in 1995 [3]. A large body of evidence indicates that adiponectin has potential anti-inflammatory properties [4, 5]. Adiponectin mimics 3 major effects of insulin: (1) it promotes increased glucose uptake and oxidation, (2) it reduces the expression of molecules involved in gluconeogenesis in the liver, and (3) it increases fatty acid oxidation in muscles through increasing molecules involved in fatty acid oxidation such as acyl-CoA oxidase [6]. The molecular mechanisms of vascular protective effects include inhibition of tumor necrosis factor-α-stimulated adhesion of monocytes to endothelial cells. Adhesion of monocytes to the vascular endothelium and the consequent transformation into foam cells may be considered fundamental for the development of vascular diseases [7]. Adiponectin inhibits the adhesion of monocytes to the endothelium and reduces the production of cytokines by macrophage phagocytosis. Adiponectin levels may be a useful marker of adipose tissue as an endocrine organ capable of hormone and cytokine production [8]. This study aimed to delineate the relation between glycemic control and adiponectin levels and its impact on carotid intima media thickness (cIMT) in lean, newly diagnosed type-1 diabetic children.

Materials and Methods

This study was a case-control study. It was performed on 46 children and adolescents with DM1 attending the Pediatric Endocrinology Clinic of the Suez Canal University, Ismailia. The study was conducted between April 1 and November 1, 2009. 46 healthy age- and sex-matched children were included as a control group. All children were normotensive, normoalbuminuric, and had no retinopathy. Those who received regular medication that can affect carotid intima media thickness such as aspirin or cholesterol-lowering drugs were excluded. Height, weight, and Body Mass Index were measured according to the Egyptian growth curves. Pubertal maturation was assessed [9]. Good glycemic control was defined as an average annual HbA1c < 7% and poor glycemic control as an average HbA1c > 9%.

Laboratory Investigation

Lipid Profile

Venous blood samples were taken in the morning after an overnight fast (10-12 h). Total serum cholesterol and triglyceride concentrations were measured using standard enzymatic methods [10]. Glycosylated hemoglobin (HbA1c) was determined by quantitative colorimetric determination of glycohemoglobin in whole blood [11]. Adiponectin was measured by enzyme-linked immunosorbent assay (ELISA). AviBion Human adiponectin enzyme-linked immunosorbent assay kits were used for monitoring serum adiponectin levels.

Carotid Artery Studies

Doppler ultrasound on carotid arteries was performed using a Philips HD11, linear array probe 12 MHz. The estimation of cIMT was done at the Radiology Department, Suez Canal University Hospital. The child was in supine position. The same experienced doctor scanned all children and used the same equipment. He was blinded to clinical and laboratory characteristics. All studies were done following a predetermined standardized scanning protocol for the right and left carotid arteries, using images of the far wall of the distal com-
mon carotid arteries and carotid bulbs according to the Mannheim common carotid IMT consensus [12]. Each CCA segment was measured. Four measurements of the intima media thickness were averaged to yield the mean common carotid intima media thickness for each side.

Data Analysis
All data were collected and statistically analyzed using SPSS 14. Numerical data were expressed as mean ± standard deviation (SD). Non-numerical data were expressed as percentage. The mean was compared using the unpaired Student’s t test. P < 0.05 was considered statistically significant. Between-group comparisons were made using ANOVA to analyze differences between cases and controls. The Pearson correlation was calculated to determine univariate relationships. Multiple regression analysis was performed to determine predictive variables for carotid IMT.

Ethical Consideration
This study was performed after obtaining written parental consent.

Results
All subjects were matched for age, sex, and BMI, as shown in Table 1. Adiponectin levels were significantly lower in children with diabetes (10.1 ± 1.57 mg) than in the control group, their annual HbA1c was < 7 % (11.23 ± 1.14; p > 0.03). Diabetic children had a significantly higher cIMT (0.56 ± 0.06 mm) than the control group (0.43 ± 0.04; p = 0.001; Table 1).

Adiponectin levels were significantly lower (8.9 ± 0.9 mg) in children with pubertal onset compared with prepubertal onset of diabetes (10.68 ± 1.41 mg; p = 0.0001). Carotid intima media thickness was significantly higher (0.59 ± 0.03 mm) in children with pubertal onset compared with prepubertal onset of diabetes (0.53 ± 0.07 mm; p = 0.003; Table 1).

Adiponectin levels were significantly lower in diabetic children with poor metabolic control (9.43 ± 1.38 mg) than in those with good metabolic control (11.51 ± 0.45 mg; p = 0.004). Carotid intima media thickness was significantly higher in diabetic children with poor metabolic control (0.57 ± 0.05 mm) than in those with good metabolic control (0.45 ± 0.03 mm; p < 0.01). Diabetic children with good metabolic control (annual HbA1c < 7 %) had no significant difference in adiponectin levels when compared to controls (11.51 ± 0.45 mg and 11.23 ± 1.14 mg, respectively; p = 0.82; Table 2).

Carotid intima media thickness correlated negatively with adiponectin (p = 0.007; Figure 1) and positively with age (p = 0.005), age at onset of diabetes (p = 0.001), duration of diabetes (p = 0.001), and HbA1c (p = 0.002).

Multivariate regression model including cIMT as dependent variable and adiponectin, age, age at onset, duration, BMI, and HbA1c as independent variables adjusted for blood pressure, height, and total cholesterol level, the most fitting factor that can predict cIMT was adiponectin (p = 0.01), duration of DM1 (p = 0.001), and BMI (p = 0.0001). Multivariate regressions were constructed to determine factors predicting adiponectin levels as dependent variables and BMI, HbA1c, and duration of diabetes as independent variables. HbA1c represents a strong and independent determinant of adiponectin levels (p = 0.0005), followed by duration of diabetes (p = 0.01) and BMI (p = 0.03).

Discussion
The effect of increasing hyperglycemia on the risk of CVD mortality is more profound in type-1 than in type-2 diabetic subjects [13]. In experimental studies, adiponectin has been shown to exert anti-inflammatory, anti-atherosclerotic, and insulin-sensitizing effects, and to inhibit neointimal thickening.

Table 1. Adiponectin levels and cIMT in children with DM1 and in the control group.

<table>
<thead>
<tr>
<th></th>
<th>Study group</th>
<th>Control group</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>n</td>
<td>46</td>
<td>46</td>
<td>–</td>
</tr>
<tr>
<td>Age (years)</td>
<td>13.63 ± 3.64</td>
<td>12.5 ± 3.02</td>
<td>0.14</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>46.65 ± 17.24</td>
<td>44.33 ± 11.74</td>
<td>0.49</td>
</tr>
<tr>
<td>Height (m)</td>
<td>1.47 ± 0.19</td>
<td>1.5 ± 0.14</td>
<td>0.43</td>
</tr>
<tr>
<td>BMI (kg/m²)</td>
<td>20.56 ± 3.54</td>
<td>19.32 ± 2.43</td>
<td>0.07</td>
</tr>
<tr>
<td>Adiponectin (mg)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>– Prepubertal onset of DM1</td>
<td>10.68 ± 1.57</td>
<td>11.23 ± 1.14</td>
<td>0.03</td>
</tr>
<tr>
<td>– Pubertal onset of DM1</td>
<td>8.9 ± 0.9</td>
<td></td>
<td></td>
</tr>
<tr>
<td>cIMT (mm)</td>
<td>0.56 ± 0.06</td>
<td>0.43 ± 0.04</td>
<td>0.001</td>
</tr>
<tr>
<td>– Prepubertal onset of DM1</td>
<td>0.53 ± 0.07</td>
<td></td>
<td>0.003</td>
</tr>
<tr>
<td>– Pubertal onset of DM1</td>
<td>0.59 ± 0.03</td>
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</table>

Table 2. Adiponectin levels and cIMT in children with good and poor metabolic control, children with DM1, and in the control group.

<table>
<thead>
<tr>
<th></th>
<th>DM1 with poor metabolic control</th>
<th>DM1 with good metabolic control</th>
<th>Control group</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Adiponectin (mg)</td>
<td>9.43 ± 1.38</td>
<td>11.51 ± 0.45</td>
<td>11.23 ± 1.14</td>
<td>0.01</td>
</tr>
<tr>
<td>cIMT (mm)</td>
<td>0.57 ± 0.05</td>
<td>0.45 ± 0.03</td>
<td>0.43 ± 0.04</td>
<td>0.002</td>
</tr>
<tr>
<td>Difference between groups</td>
<td>0.01</td>
<td>0.0001</td>
<td>0.15</td>
<td>0.004</td>
</tr>
<tr>
<td>Poor control vs control group</td>
<td>0.002</td>
<td>0.001</td>
<td>0.01</td>
<td>0.01</td>
</tr>
<tr>
<td>Good control vs control group</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Poor control vs good control</td>
<td></td>
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</table>

Figure 1. Correlation between adiponectin and cIMT in children with DM1.
ing and vascular smooth muscle cell proliferation in mechanically injured arteries [14]. The thickness of cIMT is an excellent surrogate marker of cardiovascular risk [15]. The prevalence of subclinical atherosclerosis as estimated by cIMT is significantly increased in DM1 youths relative to controls [16]. An increase of 0.2 mm of cIMT was associated with a 28%-increase in the likelihood of incident stroke. The present study showed significantly increased cIMT in diabetic children (0.56 ± 0.06 mm) compared to the control group (0.43 ± 0.04 mm; p < 0.001). Similar results were reported by others [17–21]. These findings extend to observations of postmortem studies that have indicated a relation between early atherosclerotic vascular lesions and diabetic state [22]. The prevalence of subclinical atherosclerosis as estimated by cIMT is significantly increased in DM1 youths relative to controls [20, 23]. However, other studies were unable to demonstrate increased carotid thickening in children with a short and longer duration of diabetes [24, 25]. Differences in methodology and study population may offer an explanation for the discrepancy. Chronic states of hyperglycemia may induce atherogenesis by increasing oxidative stress leading to increased LDL oxidation [26] and decreased nitric oxide bioavailability, inducing endothelial dysfunction [27]. The present study showed a positive, statistically significant correlation between mean carotid intima media thickness and both age of diabetic subjects (r = 0.88; p < 0.001) and age at onset of diabetes (r = 0.71; p < 0.001). Carotid intima media thickness was 0.534 ± 0.072 mm in prepubertal onset of diabetes versus 0.59 ± 0.039 mm in pubertal onset of diabetes with a statistical significance of p < 0.001. Both Arwa et al [18] and Abdelghaffar et al [19] reported a statistically significant positive correlation between mean cIMT and age of diabetic subjects. This does not suggest that early ages of onset are protective but rather that “the clock does not run as fast” for the years before pubertal onset. Donaghue et al [28] also reported that prepubertal duration of diabetes contributes less than pubertal duration to the risk of diabetic complications. The mechanism behind this effect of age at onset is not clear, but it has been speculated that puberty, characterized by both rapid growth, hormonal changes, and worsening in glycemic control, may accelerate the processes leading to chronic diabetes complications [29].

There was a statistically significant positive correlation between mean cIMT and duration of DM1 of diabetic subjects (r = 0.75; p < 0.001). Rodriguez et al [30], Arwa et al [18], Abdelghaffar et al [19], and Jarvisalo et al [20] also reported a positive, statistically significant correlation between mean cIMT and duration of DM1 of diabetic subjects. Prolonged exposure to hyperglycemia is recognized as the primary casual factor in the pathogenesis of diabetic complications [31, 32]. There was a statistically significant positive correlation between mean carotid intima media thickness and HbA1c of diabetic subjects (r = 0.81; p = 0.001). The mechanism behind this effect of age at onset is not clear, but it has been speculated that puberty, characterized by both rapid growth, hormonal changes, and worsening in glycemic control, may accelerate the processes leading to chronic diabetes complications [29].

The findings of Pozza et al [47] are in agreement with our results: they found that plasma adiponectin levels (mean 9.1 ± 3.1 μg/ml) were negatively correlated with the age of diabetic subjects (r = –0.78; p < 0.0001) and age of diabetic subjects (r = –0.89; p < 0.002). The findings of Galler et al [48] are in agreement with our results: they found that plasma adiponectin levels (mean 9.1 ± 3.1 μg/ml) were negatively correlated with the age of diabetic subjects (p < 0.04). Our study showed a statistically significant negative correlation between adiponectin levels and duration of DM1 (r = –0.83; p = 0.001). Galler et al [48] also reported a statistically significant positive correlation between mean carotid intima media thickness and HbA1c of diabetic children. This explains the value of glycemic control in preventing or minimizing macrovascular complications. The study showed a significantly negative correlation between mean carotid intima media thickness and serum adiponectin levels of diabetic subjects (r = –0.74; p < 0.002). Adiponectin infiltrates in the subendothelial space of injured vascular walls and suppresses expression of adhesion molecules on endothelial cells, thus inhibiting sub-inflammatory processes that occur during early phases of atherosclerosis. It also inhibits the production and action of TNF-α and suppresses the transformation of macrophages into foam cells, which is the link between vascular inflammation and atherosclerosis. The cellular antiatherosclerotic effect of adiponectin is documented by its capacity to inhibit growth factors in smooth vascular musculature and reduction of macrophage migration [33]. So the ability of adiponectin to act as an anti-inflammatory and antiatherogenic factor has made this novel adipocytokine a promising therapeutic tool for the future [34]. Cardiovascular disease is the most frequent cause of death in DM1, with a 10 times, increased, CVD-related all-cause mortality compared with the general population [35, 36], despite modern advances in glycemic control and CVD risk factor modification [37, 38]. Other studies showed that adiponectin suppresses various mechanisms contributing to atherogenesis [39–42] and our results are consistent with this background. This may explain the negative correlation between mean carotid intima media thickness and serum adiponectin levels of diabetic children in our study. The study showed that the lean diabetic group had significantly lower serum adiponectin levels compared with control subjects. Adiponectin levels in the diabetic group were 10.1 ± 1.57 versus 11.23 ± 1.14 in the control group (p < 0.001). Studies in DM1 children are limited and the results were controversial. Celi et al [43] found that circulating adiponectin concentrations were higher in prepubertal diabetic children compared with healthy children. Morales et al [44] found that there was no significant difference between adiponectin levels in DM1 children compared with controls. They were 10.2 μg/ml in diabetic children versus 10.6 μg/ml in controls. Martos-Morales et al [45] found that study diagnosis, adiponectin levels in prepubertal children with newly diagnosed DM1 were similar to controls; after one month, adiponectin levels increased and normalized at month 4. Abu El-Yazid et al [46] showed that serum adiponectin is lower in diabetic patients compared to control groups. This difference in adiponectin levels in children with DM1 in various studies may be due to differences in ethnic groups, methodology, population size, mean age of study population, and differences in diabetic control. The lower adiponectin levels in the present study may be explained by the fact that all children were normoalbuminuric along with ethnic variation. Adiponectin can be glycosylated and hydroxylated; consequently, modified adiponectin could lead to diminished negative feedback and thus to increased adiponectin concentrations. In the present study, there was a statistically significant negative correlation between adiponectin levels and both age of onset of diabetes (r = –0.78; p < 0.0001) and age of diabetic subjects (r = –0.89; p < 0.002). In agreement with our results, Celi et al [47] found that circulating adiponectin concentrations were higher in prepubertal diabetic children and were positively associated with HbA1c, while Galler et al [48] failed to find a significant difference of adiponectin levels regarding gender, diabetes duration, or HbA1c.
Conclusion

Glycemic control may have crucial impact to prevent atherosclerotic changes in DM1 children with a short duration of diabetes. Diabetic children with good metabolic control and a short duration of diabetes had no significant difference in adiponectin levels when compared to healthy children.

References:


ORIGINAL PAPERS, CLINICAL CARDIOLOGY

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