Introduction

Increasing evidence suggests that increased oxidative stress, associated with diabetes mellitus, might play an important role in the initiation and progression of diabetic complications such as retinopathy, neuropathy and nephropathy (2,5,28). This hypothesis is supported by evidence that many biochemical pathways e.g., glucose autoxidation, polyol pathway, prostaglandin synthesis and protein glycation, tightly associated with hyperglycemia, can increase the production of free radicals (5).

Diabetic retinopathy (DR) is the most common cause of legal blindness in individuals between the ages of 20 and 65 years. DR is a microangiopathy affecting the retinal pre-capillary arterioles, capillaries and venules. However, larger vessels may also be involved. Retinopathy has features of both microvascular occlusion and leakage. Clinically, the three main types of DR are background, preproliferative and proliferative (12). Although hyperglycaemia has been identified as the major underlying factor of retinopathy, the complex cascade of events leading to vascular occlusions remains undefined. Potential pathogenetic mechanisms include platelet dysfunction, increased blood viscosity in association with impaired cell deformability and pathologic leukocyte/endothelium interaction (8). Chronic hyperglycemia affects cellular and matrix function by a variety of mechanisms such as increased polyclonal activity, altered intracellular redox state, activation of protein kinase C, non-enzymatic glycation and increased free radical damage (8,9,15).

Reactive oxygen species, such as superoxide radical, hydrogen peroxide, and hydroxyl radical, are constantly formed by activated phagocytes and by other mechanisms in the human body and removed by antioxidant defenses. Popular antioxidants include vitamins E and C, carotenoids, glutathione, ubiquinol, uric acid, and antioxidant enzymes. Among these enzymes, superoxide dismutase (SOD) catalyses dismutation of superoxide anion ($O_2^-$) into $H_2O_2$, and both catalase (CAT) and glutathione peroxidase (GSH-Px) detoxify $H_2O_2$ and convert lipid hydroperoxides to nontoxic alcohols (6,7,11).

There are several reports on plasma (16,21) and erythrocyte (14,31) lipid peroxidation (LPO) and antioxidant enzymes in diabetes, but few studies have been devoted to leukocyte antioxidants status and DR. Prospective studies are needed to evaluate the relationship between the leukocyte antioxidants status and DR.
Tab. 1: Characteristics of subjects and comparison of parameters of patients with diabetes and controls.

|                | Control (n=23) | NDR (n=16) | BDR (n=7) | PrePDR (n=8) | PDR (n=10) | DM (n=41) | T2DR (n=25) |
|----------------|---------------|------------|-----------|--------------|------------|-----------|-------------|
| Age (years)    | 53.55±6.72    | 59.00±6.96 | 55.85±6.91| 54.25±8.03   | 57.00±5.37 | 57.04±7.29| 55.80±7.35 |
| Duration of DM (years) | -            | 2.62±1.85a | 5.85±4.77 | 11.75±3.99ac | 15.10±4.43ac| 8.00±6.30ac| 11.44±5.69ac|
| HbA1c (%)      | 5.73±1.51     | 7.94±1.94c | 8.14±2.72de| 9.05±1.16b   | 11.58±2.05ac| 9.08±2.25a | 9.80±2.16af |
| SOD (U/mg protein) | 21.91±8.81   | 11.50±3.74a| 10.34±2.45a| 7.30±1.83a   | 6.48±2.31a | 9.25±3.58a | 7.82±2.68a  |
| CAT (k/mg protein) | 2.04±0.10±3  | 7.94±0.10±3| 7.29±0.10±3| 5.88±0.10±3a | 5.30±0.10±3 | 6.78±0.10±3 | 6.04±0.10±3 |
| MDA (nmol/mg protein) | 2.42±0.60    | 3.95±0.98ad| 4.19±1.11b | 4.30±0.76a   | 5.54±1.72a | 4.45±1.31a | 4.76±1.42a  |

Values represent means ± SD; DM, Diabetes Mellitus; NDR, diabetic group no diabetic retinopathy; BDR, background diabetic retinopathy; prePDR, preproliferative diabetic retinopathy; PDR, proliferative diabetic retinopathy; T2DR, type 2 diabetic retinopathy; SOD, superoxide dismutase; CAT, catalase; MDA, malondialdehyde.

Therefore, the present study has been undertaken to investigate whether there is any relationship between retinopathy degree and leukocyte SOD and CAT activities and LPO in diabetic individuals with type 2 DR.

Materials and Methods

Fourty-one type-2 diabetic patients were included in this study (19 males, 22 females aged 43–74 years). Patients were classified into subgroups with respect to the degree of retinopathy after examination by a specialist in the ophthalmology department, including no diabetic retinopathy (NDR), background diabetic retinopathy (BDR), pre-proliferative diabetic retinopathy (prePDR), and proliferative diabetic retinopathy (PDR). Following definitions were used: BDR consists of microaneuvers, dot and blot hemorrhages, hard exudates and retinal edema; pre-PDR consists of cotton wool spots, venous changes such as dilation, beading, looping, and sausagelike segmentation, arteriolar narrowing and large dark blot hemorrhages; PDR consists of neovascularization, vitreous changes, and integral or preretinal hemorrhages. Informed consent was obtained from all subjects. The control group consisted of 23 healthy controls (10 males, 13 females aged 37–63 years). The absence of diabetes was checked in these individuals before each examination by a specialist in the ophthalmology department, including no diabetic retinopathy. Blood sample taken, and none of the subjects in this study had hypertension and no one was smoking and taking alcohol. Characteristics of subjects are shown in Table 1. Blood fasting glucose was determined by routine method (27). CAT and SOD activities were measured as previously described Luck by and Sun, respectively (19,27). Activities of the enzymes were calculated as U/mg protein for SOD and as k/mg protein for CAT. The principle of the assay for the CAT activity is based on the determination of the rate constant (s⁻¹, k) of hydrogen peroxide decomposition by CAT enzyme.

Blood fasting glucose was determined by routine methods using glucose oxidase in an autoanalyser (Hitachi 717: Hitachi, Tokyo, Japan). HbA1c was estimated by a commercially available kit based on column chromatography (Biosystems, Barcelona, Spain). All the experimental procedures were performed at +4 °C.

Data are expressed as mean ± standard deviation (SD). Statistical analyses were conducted by analysis of variance (ANOVA) following by Tukey test. Pearson correlation analysis was used to detect relationship between variables in the diabetic and control groups. The criterion for statistical significance was p < 0.05.

|                | Control (n=23) | NDR (n=16) | BDR (n=7) | PrePDR (n=8) | PDR (n=10) | DM (n=41) | T2DR (n=25) |
|----------------|---------------|------------|-----------|--------------|------------|-----------|-------------|
| Duration of DM (years) | -            | 2.62±1.85a | 5.85±4.77 | 11.75±3.99ac | 15.10±4.43ac| 8.00±6.30ac| 11.44±5.69ac|
| SOD (U/mg protein) | 21.91±8.81   | 11.50±3.74a| 10.34±2.45a| 7.30±1.83a   | 6.48±2.31a | 9.25±3.58a | 7.82±2.68a  |
| CAT (k/mg protein) | 2.04±0.10±3  | 7.94±0.10±3| 7.29±0.10±3| 5.88±0.10±3a | 5.30±0.10±3 | 6.78±0.10±3 | 6.04±0.10±3 |
| MDA (nmol/mg protein) | 2.42±0.60    | 3.95±0.98ad| 4.19±1.11b | 4.30±0.76a   | 5.54±1.72a | 4.45±1.31a | 4.76±1.42a  |

Values represent means ± SD; DM, Diabetes Mellitus; NDR, diabetic group no diabetic retinopathy; BDR, background diabetic retinopathy; prePDR, preproliferative diabetic retinopathy; PDR, proliferative diabetic retinopathy; T2DR, type 2 diabetic retinopathy; SOD, superoxide dismutase; CAT, catalase; MDA, malondialdehyde.
Results

Results are given in Table 1. Leukocyte LPO of the patients with type 2 DM was significantly increased (4.45 ± 1.31 vs 2.42 ± 0.60 nmol/mg protein, p < 0.001), whereas SOD and CAT activities were decreased (9.25 ± 3.58 vs 21.91 ± 8.81 U/mg protein, p < 0.001 and 6.78.10^{-3} ± 2.80.10^{-3} vs. 2.04.10^{-2} ± 9.38. 10^{-3} k/mg protein; p < 0.001, respectively) compared with those of controls. In addition, there was an inverse relationship between the severity of DR and SOD and CAT activities. MDA concentrations rose (4.19 ± 1.1 for BDR; 4.3±0.76 for pre-PDR; and 5.54 ± 1.7 nmol/mg protein for PDR), while SOD (10.3 ± 2.4 for BDR; 7.3 ± 1.8 for pre-PDR; and 6.4 ± 2.3 U/mg protein for PDR) and CAT (7.2.10^{-3} ± 3.1.10^{-3} for BDR; 5.8.10^{-3} ± 1.4.10^{-3} for pre-PDR; and 5.3.10^{-3} ± 2.4.10^{-3} k/mg protein for PDR) activities fell with increasing severity of DR. However, MDA levels and SOD and CAT activities were not different in type 2 diabetic patients with retinopathy compared without retinopathy.

In correlation analysis, leukocyte MDA levels were correlated with HbA1c and duration of DM (r = 0.410; p < 0.01 and r = 0.362; p < 0.05, respectively) in diabetics. In addition, duration of DM was correlated with SOD activities and HbA1c (r = -0.379; p < 0.05 and r =-0.55; p < 0.01, respectively) in diabetics. There was, however, no significant correlation between studied parameters in patients with type 2 DR except for duration of DM and HbA1c.

Discussion

DR is a highly specific vascular complication of diabetes mellitus. Oxidative stress is believed to play a significant role in the development of diabetic retinopathy. Uzel et al. demonstrated the elevation of lipid peroxide levels in plasma and erythrocyte of diabetic patients with retinopathy compared to without retinopathy and to no diabetic control group, and therefore it is suggested that the elevation of LPO in the blood of diabetics may be a cause of retinopathy (31). Also, Kowluru et al. demonstrated elevated lipid peroxides in retina and plasma from diabetic rats (16). In another study, Akkus and co-workers have shown that leukocyte lipid peroxidation of diabetics was increased (1). Impaired polymorphnuclear leukocyte (PMNL) functions have been observed in poorly controlled diabetics (20). On the other hand, activation of leukocytes and monocytes has been associated with retinal vascular occlusion in diabetic rats (24), which is important source of oxygen free radicals. However, in literature review, we could find no study related to leukocyte antioxidants and LPO in the DR.

In this study, an increase in LPO was associated with severity of DR, with the highest levels being in the PDR group. We also observed that the leukocyte SOD and CAT activities in patients with type 2 DR were lower than those in nondiabetic healthy subjects and than those in diabetic patients without retinopathy. In addition, severity of DR was inversely related to leukocyte SOD and CAT levels, and they were the lowest in the PDR group for both parameters.

Du et al. showed that diabetes-like glucose concentration increases superoxide production in retinal cells, and the superoxide contributes to impaired viability and increased cell death under those circumstances (3). Yang et al. reported that high concentrations of glucose cause generation of superoxide; a consequent prolonged superoxide excess can impair cellular function (33). On the other hand, generation of oxygen free radicals during interactions which related with hyperglycemia has been confirmed by the findings of increased superoxide anion radical production in both plasma and PMNL (32). Furthermore, exposure of endothelial cells to high glucose leads to augmented production of superoxide anion, which may quench nitric oxide, a potent endothelium-derived vasodilator that participates in the general homeostasis of the vasculature (5). Although SOD provides effective intracellular defence against superoxide radical-mediated toxicity, this scavenging system might be impaired in diabetes due to diminished synthesis and/or deactivation of the enzyme by glycation. In previous studies, there are inconsistent findings concerning leukocyte SOD activity in diabetes. Vučić found that SOD activity in lymphocytes and PMNL was significantly lower than that of controls in both type 1 and type 2 DM (32). Also, Uchimura et al. found that Cu, Zn-SOD and Mn-SOD activities in neutrophils and lymphocytes were significantly lower in patients with type 2 DM than in healthy controls (30). Our results confirm the results of these studies. In contrast, Akkus reported no significant change in leukocyte SOD activity in type 2 diabetic patients (1).

On the other hand, H2O2, an important reactive oxygen species in human pathology, is metabolized to H2O by CAT (7). In several studies, plasma, erythrocyte, leukocyte and tissue CAT activities are reported in diabetic humans and rats, but findings of these studies are controversial. For example, Strother reported that decreased hepatic and increased cardiac CAT activity were observed in diabetic rats when compared to normal (26). Kesavulu reported that erythrocyte CAT activity was increased in the type 2 diabetic patients compared with those in controls (14). Türk found that plasma CAT activity was significantly decreased in the type 2 diabetic patients when compared with the control group (29). In spite of this, Muchova reported that CAT activity showed no significant difference in PMNL from patients with type 2 DM when compared with controls (22). The finding does not agree with our results, since in our study, CAT activity was lower in patients with or without DR than that of controls. Additionally, there was an inverse relationship between the severity of DR and CAT activity. The significant decrease in CAT activity could be due to glycation of the enzyme or generation of H2O2 in large amounts.

The decrease reactivity of the SOD and increase in H2O2 concentrations lead to generation of the hydroxyl radicals from the Fenton’s type reaction. The subsequent
hydroxyl radical induces the generation of superoxide radical, leading to peroxidation (23). In addition, erthrocyte HbA1c, a marker of glycation and an important risk factor for the progression for DR, was correlated with leukocyte MDA in diabetics in present study. This finding is in accordance with that of Jain (10), who found erthrocyte membrane LPO to be increased and correlated with HbA1c levels in diabetics but inconsistent with that of Akkus and co-workers (1), who found no correlation between leukocyte LPO and HbA1c. However, a weak correlation was found between HbA1c and SOD and CAT activities in diabetics in our study. In addition, we found the significant correlations between SOD and MDA and duration of diabetes, which is a significant risk factor for the development of retinopathy (15). Several controlled clinical trials have documented the efficiency of α-tocopherol in minimizing the retinopathy, suggesting a role for LPO (6). It was reported that diabetes-induced increased oxidative stress in the retina can be inhibited by dietary supplementation with antioxidants (16, 17). Also, vitamin C has been shown to help improve the effects of retinopathy (25).

From these previous reports, it has been understood that there is a close relationship between the leukocyte function disorders and diabetes and DR and also that oxidative stress plays an important role in the progression of the retinopathy. Our results, however, show the contribution of the inadequate antioxidative defence in leucocytes to the progression of retinopathy in diabetes. As far as we are concerned, it is our study that shows the relation of leukocyte antoxidants and LPO to DR.

It can be concluded from our results that leukocyte CAT and SOD activities decrease and LPO increases in type 2 diabetic patients with or without retinopathy. Moreover, severity of retinopathy is related to the defects of antioxidant protection. Therefore, one should consider that the increase in production of free radicals and impairment of the antioxidative defense mechanisms have a role on the pathogenesis of DR. However, further studies are needed to confirm the relationship of the antioxidiant status and progression of DR.

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