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The Effects of Weight Loss on Blood Rheology in Obese Patients

Maciej Wiewiora*, Jerzy Piecuch and Krystyn Sosada

Department of General and Bariatric Surgery and Emergency Medicine in Zabrze, Medical University of Silesia, Poland

***Corresponding author:** *Maciej Wiewiora, ul. Sklodowskiej-Curie10, 41-800 Zabrze, Poland, Tel: 48 32 3732381, Fax: 48 32 2716335, E-mail: m-wiewiora@tlen.pl.*

Abstract

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Hemorheological alterations in obesity, including disturbances in the blood's rheological behavior such as increased blood and plasma viscosity and enhanced red blood cell (RBC) aggregation, have been reported by various authors [1-4]. Blood and plasma viscosity are risk factors for arteriosclerosis [5-7]. Other studies have shown that erythrocyte rheological changes have been observed in patients with hypertension [8] and diabetes mellitus [9], which are more often associated with obesity. Obesity-related blood rheological disturbances are currently being investigated as one of the risk factors for several co-morbid pathologies because they play a significant role in blood flow in microcirculation. Blood is a non-Newtonian fluid. Thered blood cells (RBCs) are one of the important determining influences on low shear blood viscosity and the degree of non-Newtonian flow behavior. In terms of rheology, blood, which is a suspension of cell elements in plasma, is an example of a liquid that does not follow Newton's laws. This means that the viscosity of blood under given stress conditions and temperatures is not constant and depends on the velocity gradient (shear rate). At low shear rates, the main index of viscosity and the degree of non-Newtonian blood properties is erythrocyte aggregation. Higher shear rates reduce the degree of aggregation and thereby blood viscosity. Generally, increasing blood viscosity with increasing RBC aggregates form rouleaux structures with larger geometries at low shear rates. During blood flow in microcirculation, the RBCs migrate axially to the center of the flow stream, which results in RBC concentration at the core and a peripheralcell-free layer that develops near the vessel wall. Studies have shown that the axial accumulation of RBCs in *ex vivo* investigations into the tube flow [10] and the microcirculation in animal models [11] result in a two-phase flow consisting of a core of aggregates and a cell-free layer. Axial accumulation is caused by the axial migration of red blood cells in the center of the flow stream, which results in RBCs concentrating at the core and a peripheral cell-free layer that develops near the vessel wall, and minimizes the resistance of blood flow. The ability of RBCs to aggregate into the slow-moving plasma layer is most important in determining the effects of this hydrodynamic resistance at low flow rates in tubes and capillaries. This blood flow structure is the result of a specifically ordered disposition of the RBCs surrounded by plasma in the microvessel lumen during flow in the capillaries and in the adjacent arterioles and venules up to approximately 15-20 μm wide [12]. The blood flow structure disturbances produce disordered blood fluidity during microcirculation because of increased blood flow resistance under conditions of constant, or even increased, pressure gradient. Based on perennial studies of blood flow disturbances inside the capillary microvessels, several primary factors that produce increased blood flow resistance in the narrowest blood vessels are as follows: enhancement of the RBC aggregation, lowered RBC deformability, increased local hematocrit and increased local blood plasma viscosity. The impact of a hypocaloric diet on the hemorheology of obese patients has been reported in numerous studies [2,13-17]. Several studies concerned with the influence of a hypocaloric diet on RBC aggregation in obese patients reported that weight loss after dieting in obese patients normalized the aggregation of the RBCs, affecting a corresponding improvement in the erythrocyte aggregation index [13-15]. Other authors have showed the absence of improvement in rheological parameters, including RBC aggregation, after weight loss associated with a low-calorie diet [2,16]. Solá et al. (2004) showed that a very low-calorie diet of 458 kcal/day reduced erythrocyte aggregation in one month; however, a prolonged low-calorie diet (1500 kcal/day) did not provide additional benefit for red cell aggregation, which returned to its basal value after 3 months of follow-up [17]. The impact of a hypocaloric diet on the obese patients' blood and plasma viscosities are also not conclusive. According to Poggi et al. [14], after three months of a 500-kcal/day diet, there was a reduction in blood viscosity at low shear rates by significant decreases in RBC aggregation and hematocrit levels. Fanari et al. (1993) also demonstrated that weight loss after dieting in obese patients contributed to improving plasma and blood viscosity [13]. Other studies have shown an absence of improvement in blood and plasma viscosity after weight loss associated with a low-calorie diet [14,15]. The results of research on the impact of diet on hemorheology indicated that a beneficial effect of weight loss on rheological profiles depends on the amount of weight lost and its long-term maintenance. Bariatric surgery is recognized to substantially improve body weight, obesity-associated co-morbidities and long-term survival. The influence of weight loss surgery on hemorheological parameters has been investigated in several publications. In our first papers, vertical-banded gastroplasty was shown to induce several beneficial changes

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in the level of RBC aggregation [18] 6 months after surgery. Our study showed a difference for erythrocyte aggregation and the kinetics of aggregation after surgery. Aggregation index was significantly decreased, while the aggregation half-time ($t_{1/2}$), which express the kinetics of the aggregation process significantly elongated. This was the first report on this subject in international literature. Similarly, Capuano et al. (2012) observed a beneficial effect of weight loss due to gastric banding on RBC aggregation at 6 months of follow-up [19]. In a recent study, we found similar changes specific to the RBC aggregation parameters at 12 months after sleeve gastrectomy [20]. We also demonstrated that effective and stable long-term weight loss from restrictive bariatric surgery modified blood rheology, including blood and plasma viscosity, in severely obese subjects 12 months after surgery [21]. We observed that sleeve gastrectomy was more effective in reducing plasma viscosity compared with gastric banding.

Conclusion

The results of studies examining the effects of diets on obesity-related hyperviscosity of blood are inconclusive; however, these studies suggested that the beneficial effects and improvement in blood and plasma viscosity disturbances depended on the amount of weight loss. Bariatric surgery is known to substantially improve body weight and obesity-associated co-morbidities, including the rheological profile. The changes in blood rheology after weight reduction surgery likely improve blood flow conditions in the microcirculation.

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