Polymer hydration and stiffness at biointerfaces and related cellular processes

This review focuses on the studies that demonstrate how hydration/dehydration affects biological processes at the cell–biomaterial interface.

Degree of hydration and water molecules binding energy depends on macromolecular chains architecture, determines the mobility of polymer chains and surface stiffness at biointerfaces, and plays an important role in controlling cytoskeletal signaling pathways in cellular processes. In a number of studies it was demonstrated that substrate stiffness is an essential factor in regulating cell proliferation and differentiation. It has been also shown that surface hydration can play a stronger role in comparison with surface stiffness in the control of platelet adhesion. The mechanical properties of extracellular matrix (ECM) to a great extent depend on properties of ECM component collagen, and the conformation and mechanical properties of collagen depend on water molecules that through water bridges stabilize triple-helical conformation of collagen.

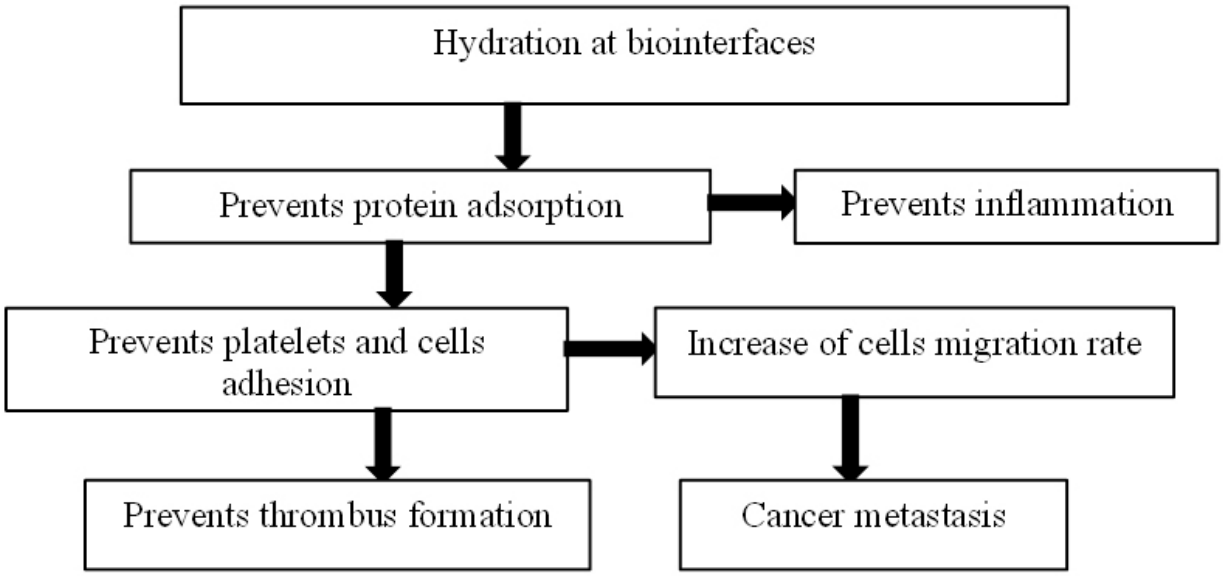

Fig. 1. The effect of hydration at biointerfaces on protein adsorption, platelet adhesion and related diseases.

The states of water have been reported as a tightly bound water, loosely bound water and bulk water. The formation of tightly bound hydration layer prevents protein adsorption at the polymer interfaces. Collagen molecules are surrounded by a hydration layer. Dehydration leads to the tighter packing of collagen fibrils and enhances stiffness by increasing intra-molecular hydrogen

bonds. Collagen is one of the main components of ECM and various tissues. So the mechanical properties of collagen play important role in many biological processes and can be linked with various age-related diseases.

It has been demonstrated that soft PEG hydrogels had minimum fibroblast cell adhesion, spreading and proliferation, but the addition of silica nanospheres significantly decreased the hydration degree, increased the mechanical strength and the toughness of the PEG hydrogels, and *increased cell adhesion*, cell spreading and the metabolic activity.

The migration rate of endothelial cells (ECs) over smooth muscle cells (SMCs) can play an important role in the acceleration of endothelialization of blood-contacting implants and in prevention of vascular restenosis.

Rates of cells migration can also be related to the rates of cancer metastasis. The migration rate of cancer cells is higher on surfaces with lower stiffness where adhesion of cells is low.

The effect of hydration at biointerfaces on protein adsorption, platelet adhesion and related diseases schematically represented at Figure 1.

The increased stiffness was reported to be an additional mechanical stimulus to promote chondrocyte growth and proliferation.

Elevated sodium and dehydration stimulate inflammatory signaling in endothelial cells and promote atherosclerosis (Fig. 2).

Many cellular processes are regulated by the changes in protein conformation and may be linked to various diseases. Water is an integral part of proteins. Conformational changes of proteins are closely related with behavior of hydration water. Water is tightly coupled to protein conformations and dynamics.

Chong and Ham at Sookmyung Women’s University, Seoul, Korea, demonstrated that water molecules play a crucial role in determining the protein aggregation propensity. It is known that protein aggregation is linked to Alzheimer’s disease, Parkinson’s disease, and type II diabetes.

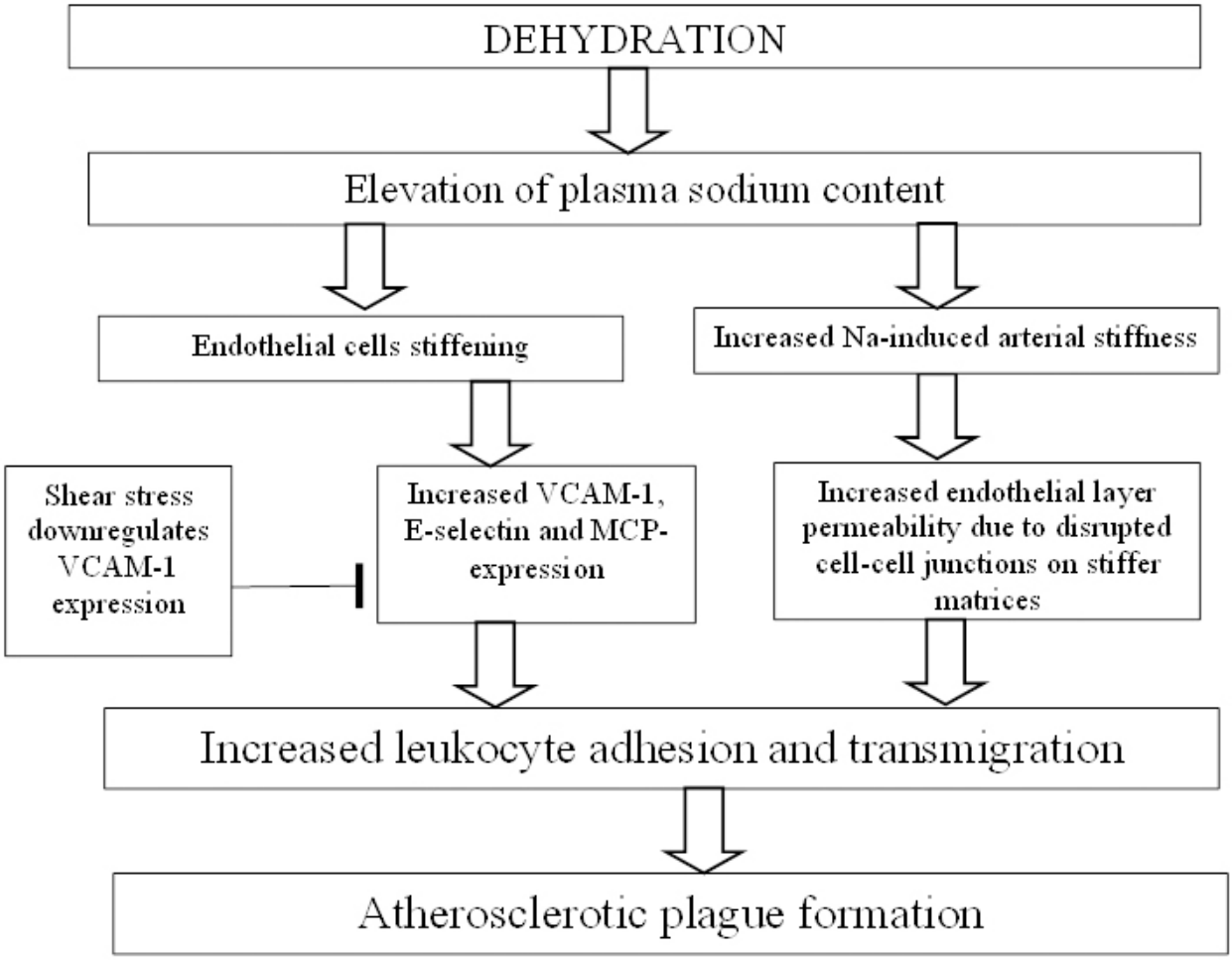

Fig. 2. Effect of dehydration on plasma sodium concentration, endothelium stiffening and related atherosclerotic plague formation.

Increase in matrix stiffness promotes cardiovascular diseases as a result of enhanced endothelial permeability and leukocyte transmigration.

Hydration/dehydration of macromolecules in ECM and in polymer coatings of implants can change surface stiffness and lead to related changes in cellular processes.

Degree of hydration and water molecules binding energy depends on macromolecular chains architecture, determines the mobility of polymer chains and surface stiffness at biointerfaces, and plays an important role in controlling cytoskeletal signaling pathways in cellular processes.

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