Reproducibility and Validity Studies

PBR = perfused boundary region

- Reflects the thickness of the endothelial glycocalyx, based on the idea that loss of its integrity allows deeper penetration of the red blood cells into the gel-like layer covering the endothelial lining.
- Higher perfused bound- ary region, therefore indicates thinner glycocalyx
- An inverse measure of the glycocalyx thickness (a marker for glycocalyx integrity)

Clinical Papers

The GlycoNurse Study
https://pubmed.ncbi.nlm.nih.gov/29444696/
Bedside analysis of the sublingual microvascular glycocalyx in the emergency room and intensive care unit – the GlycoNurse study

Kuempers 2018: good intra-observer and excellent intra-class reproducibility of PBR measurements in ICU and ER patients; increased PBR in ICU patients compared with ER patients. PBR correlates with Mean Arterial Pressure (MAP) and with CRP and SOFA scores.

Early Onset Preeclampsia
https://pubmed.ncbi.nlm.nih.gov/30764695/
Early Onset Preeclampsia Is Associated With Glycocalyx Degradation and Reduced Microvascular Perfusion

Weissgerber 2019: reproducibility of PBR measurements in pre-eclampsia patients increases when taking average of 2 or 3 measurements.

Sepsis
https://pubmed.ncbi.nlm.nih.gov/31340868/
Association of sublingual microcirculation parameters and endothelial glycocalyx dimensions in resuscitated sepsis

Kuempers 2019: PBR in patients correlates with plasma Syndecan-1 levels and with Atomic Force Microscope measurements of glycocalyx dimension on cultured endothelial cells exposed to patients' plasma.

Ischemic Heart Disease
https://pubmed.ncbi.nlm.nih.gov/29608790/
Increase in perfused boundary region of endothelial glycocalyx is associated with higher prevalence of ischemic heart disease and lesions of microcirculation and vascular wall

Gorshkov 2018: Increase of PBR is associated with ischemic heart disease.

Experimental Papers

Rapid Insulin-Mediated Increase
https://pubmed.ncbi.nlm.nih.gov/23383178/
Rapid Insulin-Mediated Increase in Microvascular Glycocalyx Accessibility in Skeletal Muscle May Contribute to Insulin-Mediated Glucose Disposal in Rats

Eskens 2013: Insulin increases PBR, and hyaluronidase treatment of the glycocalyx abolishes the insulin effect

Glycocalyx damage may contribute to the development of insulin resistance in obesity
https://pubmed.ncbi.nlm.nih.gov/24744873/
Early impairment of skeletal muscle endothelial glycocalyx barrier properties in diet-induced obesity in mice
Eskens 2014: PBR is increased in response to a High Fat Diet (figure 2D) and PBR correlates with increased duration and level of plasma glucose (area under the curve of glucose) after Glucose Tolerance Test.

Restricting endothelial hyaluronan production increases PBR
https://pubmed.ncbi.nlm.nih.gov/26071545/
Perturbed mechanotransduction by endothelial surface glycocalyx modification greatly impairs the arteriogenic process

Potter 2015: Inhibition of endothelial hyaluronan production increases PBR, which is associated with diminished glycocalyx dimension as measured with the Dextran 150kDa exclusion zone (figure 1).

Old age leads to lower endothelial glycocalyx thickness
https://pubmed.ncbi.nlm.nih.gov/29750566/
Advanced age results in a diminished endothelial glycocalyx

Machin 2018: PBR increase in old mice is associated with decreased glycocalyx dimension, and increased PBR is associated with decreased glycocalyx dimension.

Current Ongoing Studies Using GlycoCheck and Endocalyx Pro

Dietary Interventions on Glycocalyx Dimensions in South Asian Patients With Diabetic Nephropathy. (Glycotreat)

Sponsor: Leiden University Medical Center

Collaborators:
Dutch Kidney Foundation
Health Holland
Radboud University

Subsidizing Party:
Health Holland (Dutch Top Sector Life Sciences & Health)
Laan van Nieuw Oost-Indië 334,
2593 CE Den Haag
The Netherlands

Dutch Kidney Foundation
Groot Hertoginnelaan 34
1405 EE, Bussum
The Netherlands

Laboratory Sites:
Leiden University Medical Center, The Netherlands
Radboud University Medical Center, The Netherlands

Objective:
To investigate whether intervention with the dietary supplement Endocalyx™ improves the Microvascular Health Index between baseline and 3 months in type 2 diabetic South Asian patients with microalbuminuria in comparison to the placebo group.

Read the full trial information here.
https://clinicaltrials.gov/ct2/show/NCT03889236

Dietary Glycocalyx Precursor Supplementation Ameliorates Age-Related Vascular Dysfunction

Daniel R Machin, Daniel Nguyen, R Colton Bramwell, Lisa A Lesniewski, and Anthony J Donator

Daniel Machin and Tony Donato published an abstract at the Experimental Biology 2019 meeting on the effect of Endocalyx on aging in mice:

Published in The FASEB Journal (volume 33, Issue 1_supplement, 01 April 2019):

Published Online: 1 Apr 2019 Abstract Number: 828.1

Abstract

Large elastic artery stiffening and endothelial dysfunction, and associated reductions in nitric oxide (NO) bioavailability, are central features of vascular aging. We have recently demonstrated that the glycocalyx, a gel-like structure that is bound to the luminal surface of the vascular endothelium, is dysfunctional in the aged vasculature. The glycocalyx has several functions that are critical for the maintenance of a healthy vasculature. We sought to determine if chronic dietary supplementation of glycocalyx precursors (glucosamine sulfate, fucoidan, superoxide dismutase, and high molecular weight hyaluronan) could restore glycocalyx function, while concomitantly ameliorating age-related vascular dysfunction. Young (Y: 7 mo) and old (O: 30 mo) male B6D2F1 mice consumed a control (C) or glycocalyx precursor (GP: 37 mg/kg encapsulated chow provided courtesy of MicroVascular Health Solutions, LLC [U.S. Patent Serial No. 9,943,572]) diet ad libitum for 10 weeks. Glycocalyx barrier function (perfused boundary region [PBR]) was evaluated in the mesenteric microcirculation using an intravital microscope equipped with an automated capture and analysis system. PBR was ~13% higher in OC compared to YC, suggestive of an age-related impairment in glycocalyx barrier function, and this was normalized in OGP mice (Both $P<0.05$; Figure 1). At baseline, aortic pulse wave velocity (PWV), a measure of large artery stiffness, was higher in OC and OGP compared with YC mice (Both $P<0.05$; Figure 2). However, after the dietary intervention, PWV decreased by ~13% in OGP ($P<0.05$), whereas, PWV was unchanged in OC and YC mice after the 10 week period ($P>0.05$). We assessed endothelial function by endothelium-dependent dilation (EDD, maximal response to acetylcholine [ACh]) in the carotid artery. Carotid artery EDD was higher in YC and OGP compared to OC mice (92.5±2.4 and 90.7±2.3 vs. 69.0±4.9%, respectively, $P<0.05$). EDD of OGP was similar to YC mice ($P>0.05$). After incubation with the nitric oxide (NO) synthase inhibitor, L-NAME, the dilatory response did not differ between groups ($P>0.05$). NO bioavailability (max ACh dilation - max ACh+L-NAME dilation) was ~10–14 fold higher in YC and OGP compared to OC mice (Both $P<0.05$; Figure 3). Endothelium-independent dilation (vasodilation to sodium nitroprusside) was not different between groups ($P>0.05$). In young mice, GP diet did not affect any of the aforementioned measurements ($P>0.05$). In conclusion, 10 weeks of dietary GP supplementation in old mice restores glycocalyx barrier function that is accompanied by reduced aortic stiffness and augmented EDD and NO bioavailability, suggesting that the glycocalyx may be an effective therapeutic target for vascular dysfunction in older adults.

Support or Funding Information.

This study was funded in part by grants from the National Institute of Health (R01 AG040297, R01 AG048366, K02 AG045339, K99 AT010017) and US Department of Veterans Affairs (1I01BX002151).

Read the Abstract here.
https://faseb.onlinelibrary.wiley.com/doi/full/10.1096/fasebj.2019.33.1_supplement.828.1

Pilot Study in 13 Healthy Volunteers

Summary of Findings from Clinical Studies
6.3.2 Food supplement

A pilot study was conducted among 13 healthy volunteers receiving the Endocalyx food supplement. After 3 months, the Microvascular Health Index measured by SDF imaging improved by 31%. After 4 months, the Microvascular Health Index in the volunteers improved by 50%. This showed the beneficial effects of the food supplement on the microvasculature as it significantly increased capillary density and red blood cell filling percentage, and reduced the perfused boundary region (unpublished data, H. Vink).

Summary of Known and Potential Risks and Benefits
6.4.2 Food supplement

In the pilot study with Endocalyx, no serious adverse effects were reported. One side effect that was reported was dizziness, as the Endocalyx supplement lowered the systolic blood pressure. The supplement is already used in general practitioners' offices in the United States and to date; no one reported any major side effects. Studies conducted with the individual ingredients also did not report any serious adverse effects. A possible side effect may be an unknown allergic reaction to one of the ingredients of the supplement. Benefits of the Endocalyx food supplement in diabetic patients remain to be established but are mainly improving the microvascular health by supporting endothelial glycocalyx function.

Studies on Endocalyx Pro effectiveness are ongoing. For the complete list, please go to Microvascular.com/Endocalyx-Pro-Studies

https://microvascular.com/endocalyx-pro-studies/

Most Recent Published Papers Using GlycoCheck

Microvascular rarefaction in patients with cerebrovascular events
ScienceDirect 23 December 2021
Conclusion: Cerebrovascular events are associated with altered systemic microvascular perfusion.
https://www.sciencedirect.com/science/article/pii/S0026286221001709

Endothelial glycocalyx and microvascular perfusion are associated with carotid intima-media thickness and impaired myocardial deformation in psoriatic disease
Journal of Human Hypertension 25 November 2021
Conclusion: Glycocalyx thickness is reduced in psoriatic patients, which in turn impairs microvascular perfusion, and is associated with carotid IMT and impaired coronary and myocardial function.
https://www.nature.com/articles/s41371-021-00640-2

Association of Gestational Diabetes With Subclinical Cardiovascular Disease on Echocardiogram and Endothelial Function Testing (Abstract 12986)
Circulation (American Heart Association) 8 Nov 2021
Conclusion: These findings suggest that subclinical structural and functional cardiac and vascular changes may be a mechanism by which GDM causes increased risk of CVD.
https://www.ahajournals.org/doi/abs/10.1161/circ.144.suppl_1.12986

Impaired Endothelial Glycocalyx Predicts Adverse Outcome in Subjects Without Overt Cardiovascular Disease: a 6-Year Follow-up Study
Journal of Cardiovascular Translational Research 28 Oct 2021
Conclusion: ongoing study
https://link.springer.com/article/10.1007/s12265-021-10180-2

Endothelial glycocalyx integrity and microvascular perfusion are associated with novel echocardiographic markers and carotid intima-media thickness in patients with psoriasis
European Heart Journal 14 October 2021
Conclusion: Endothelial glycocalyx thickness is reduced in patients with psoriasis and is associated with impaired coronary and myocardial function, and vascular atherosclerosis.
https://academic.oup.com/eurheartj/article/42/Supplement_1/ehab724.2766/6391978?login=false

Apremilast improves endothelial glycocalyx and microvascular perfusion: a possible protective mechanism against COVID-19
European Heart Journal 14 October 2021
Conclusion: Apremilast restores glycocalyx integrity and thus reduces vascular permeability to pro-inflammatory molecules. This may explain the beneficial effects of apremilast on COVID-19. Apremilast (Otezia) is a treatment for certain types of psoriasis and psoriatic arthritis.
https://academic.oup.com/eurheartj/article/42/Supplement_1/ehab724.2764/6391980?login=false

Case Report: Endothelial Glycocalyx Damage in Critically ill Patients With SARS-CoV-2-Related Multisystem Inflammatory Syndrome (MIS-C)
Frontiers in Pediatrics 06 September 2021
Note: Endothelial insult and damage is one of the reported consequences of SARS-CoV-2 infection. It has been associated with severe inflammation, thrombotic phenomena and profound hypoxemia in critically ill patients. Endothelial activation leads to a loss of the endothelium's antithrombotic properties which, under normal conditions, are maintained by the endothelial glycocalyx, a carbohydrate-rich layer that covers the luminal surface of endothelial cells. In children, one of the serious forms of SARS-CoV-2 virus disease (COVID-19) is multisystem inflammatory syndrome (MIS-C). This new disease is characterized by a large inflammatory response and frequent cardiovascular, cutaneous and gastrointestinal disorders.
https://www.frontiersin.org/articles/10.3389/fped.2021.726949/full

Association of COVID-19 with impaired endothelial glycocalyx, vascular function and myocardial deformation four months after infection
European Journal of Heart Failure. 20 August 2021
Conclusion: SARS-CoV-2 may cause endothelial and vascular dysfunction linked to impaired cardiac performance 4 months after infection.
https://onlinelibrary.wiley.com/doi/full/10.1002/ejhf.2326

Microvascular Differences in Individuals With Obesity At Risk of Developing Cardiovascular Disease Obesity
A Research Journal. 2 August 2021
Conclusion: Able to detect microcirculatory differences in a cohort of individuals with obesity at risk for developing cardiovascular disease.
https://onlinelibrary.wiley.com/doi/full/10.1002/ejhf.2326

Links between Endothelial Glycocalyx Changes and Microcirculatory Parameters in Septic Patients
MDPI (Multidisciplinary Digital Publishing Institute) 5 August 2021
Conclusion: Our data suggest that there may be a functional relationship between damage to the endothelial glycocalyx of the smallest capillaries and alterations in the microcirculation observed in response to sepsis.
https://www.mdpi.com/2075-1729/11/8/790

May We Use Non-Invasive Indices of Aortic Stiffness and Endothelial Glycocalyx as Biomarkers for Idiopathic Pulmonary Artery Hypertension Follow-Up?
MDPI (Multidisciplinary Digital Publishing Institute) 25 May 2021
https://www.mdpi.com/1648-9144/57/6/558/htm
Critical Care, 19 March 2021(link to PDF)

Identification of novel sublingual parameters to analyze and diagnose microvascular dysfunction in sepsis: The NOSTRADAMUS study (link to Critical Care)
Critical Care, 19 March 2021 (link to PDF)
https://ccforum.biomedcentral.com/articles/10.1186/s13054-021-03520-w

Vascular Endothelial Glycocalyx Damage in COVID-19
International Journal of Molecular Sciences, December 2020
https://www.researchgate.net/publication/347486326_Vascular_Endothelial_Glycocalyx_Damage_in_COVID-19

Microvascular dysfunction in COVID-19: the MYSTIC study
Angiogenesis 14 October 2020
https://link.springer.com/article/10.1007/s10456-020-09753-7

Effect of gestational age and postnatal age on the endothelial glycocalyx in neonates
Scientific Reports (Nature Publisher Group); London Vol. 11, Iss. 1, (2021)
https://www.proquest.com/openview/7e5cb51e5fe502341f83b703e339916a/1?pq-origsite=gscholar&cbl=2041939

Vascular conditioning prevents adverse left ventricular remodelling after acute myocardial infarction: a randomised remote conditioning study
Basic Research in Cardiology volume 116, Article number: 9 (2021)
https://link.springer.com/article/10.1007/s00395-021-00851-1

Effects of a single aerobic exercise on perfused boundary region and microvascular perfusion: a field study
Journal of Clinical Monitoring and Computing (2021)
https://link.springer.com/article/10.1007/s10877-021-00660-w

Assessment of the sublingual microcirculation with the GlycoCheck system: Reproducibility and examination conditions
PLoS One. 2020 Dec 23;15(12):e0243737
Smoking, meal and coffee intake had effects up to 3 hours (180 minutes), abstinence is recommended at least 3 hours (180 minutes) before GlycoCheck measurements.
https://pubmed.ncbi.nlm.nih.gov/33362252/

Evaluation of jejunal microvasculature of healthy anesthetized dogs with sidestream dark field video microscopy
Am J Vet Res. 2020 Nov;81(11):888-893.
https://pubmed.ncbi.nlm.nih.gov/33107751/

Tocilizumab improves oxidative stress and endothelial glycocalyx: A mechanism that may explain the effects of biological treatment on COVID-19
Food Chem Toxicol. 2020 Nov;145:111694.
The effects of Tocilizumab on patients with Rheumatoid Arthritis (80 patients). Tocilizumab improves endothelial function.
https://pubmed.ncbi.nlm.nih.gov/32822775/

Sex-related associations of high-density lipoprotein cholesterol with aortic stiffness and endothelial glycocalyx integrity in treated hypertensive patients
J Clin Hypertens (Greenwich). 2020 Oct;22(10):1827-1834.
Conclusion: Higher HDL-C levels are associated with reduced aortic stiffness in hypertensive patients, while they protect EG and subsequently endothelial function in middle-aged, treated hypertensive male patients (either smokers or not).
https://pubmed.ncbi.nlm.nih.gov/32790102/

Visual and Biochemical Evidence of Glycocalyx Disruption in Human Dengue Infection, and Association With Plasma Leakage Severity
Front Med (Lausanne). 2020 Oct 16;7:545813
Conclusion: We present the first human *in vivo* evidence of glycocalyx disruption in dengue, with worse visual glycocalyx damage and higher plasma degradation products associated with more severe plasma leak.
https://pubmed.ncbi.nlm.nih.gov/33178710/

Immediate effects of whole blood donation on the endothelial surface layer and glycocalyx shedding
Blood Transfus. 2020 Jul 22.
Conclusion: This study shows that within the GI setting TACO (transfusion-associated circulatory overload) may be markedly under-reported. Clinical awareness for potential TACO development in GI patients with cardiac or renal disease or age >80 years is now required.
https://pubmed.ncbi.nlm.nih.gov/33000753/

Variability of Microcirculatory Measurements in Critically Ill Patients
Shock. 2020 Jul;54(1):9-14.
Results: ICCs of single measurements were poor for glycocalyx thickness and good for filling percentage and vessel density. Reproducibility could be substantially increased for all parameters when three consecutive measurements were performed and averaged.
Discussion: GlycoCheck can be used to study microcirculation. However, to obtain reliable results three consecutive measurements should be performed and averaged. The variation of the measurements currently hampers the clinical application in individual patients.
https://pubmed.ncbi.nlm.nih.gov/31743299/

Decreased endothelial glycocalyx thickness is an early predictor of mortality in sepsis
Anaesth Intensive Care. 2020 May;48(3):221-228.
Conclusion: The PBR in 21 patients with sepsis was measured within 24 h of admission to the intensive care unit (ICU). In addition, we determined plasma markers of microcirculatory dysfunction and studied their correlation with PBR and mortality. Endothelial glycocalyx thickness in sepsis was significantly lower for non-survivors as compared with survivors. An increased PBR within the first 24 h after ICU admission is associated with mortality in sepsis.
https://pubmed.ncbi.nlm.nih.gov/32486831/

Microvascular Alterations During Cardiac Surgery Using a Heparin or Phosphorylcholine-Coated Circuit
J Cardiothorac Vasc Anesth. 2020 Apr;34(4):912-919
Conclusion: The use of an HC (heparin-coated) circuit is associated with better preservation of the endothelial glycocalyx compared with PC (phosphorylcholine-coated) circuits, whereas microcirculatory perfusion was disturbed equally in both groups. Hence, CPB-induced microcirculatory perfusion disturbances seem to be coating independent.
https://pubmed.ncbi.nlm.nih.gov/31787433/

In Vivo Imaging of the Buccal Mucosa Shows Loss of the Endothelial Glycocalyx and Perivascular Hemorrhages in Pediatric Plasmodium falciparum Malaria
Infect Immun. 2020 Feb 20;88(3):e00679-19.
Conclusion: Our findings indicate that as with experimental malaria, the loss of endothelial glycocalyx is associated with vascular dysfunction in human malaria and is related to severity.
https://pubmed.ncbi.nlm.nih.gov/31871101/

Does sublingual microscopy correlate with nailfold videocapillaroscopy in systemic sclerosis?
Clin Rheumatol. 2021 Jan 7.
Key Points: Tools that longitudinally assess microvascular function and morphologic features are important for monitoring SSc vasculopathy. • Nailfold and sublingual microscopy can identify a loss of capillary density in SSc (systemic sclerosis) patients.
https://pubmed.ncbi.nlm.nih.gov/33415452/

Non-invasive evaluation of macro- and microhemodynamic changes during induction of general anesthesia - A prospective observational single-blinded trial
Clin Hemorheol Microcirc. 2021;77(1):1-16.
Conclusion: Support of MAP (mean arterial blood pressure) by NE (norepinephrine) must consequently result from an increase in peripheral arterial resistance, posing a risk for oxygen supply to tissue. General anesthesia and the operative stimulus lead to an impairment of the microcirculation.
https://pubmed.ncbi.nlm.nih.gov/31929147/

Evaluation of endothelial glycocalyx in healthy volunteers - An observational study
Clin Hemorheol Microcirc. 2020;75(3):257-265.
Conclusion: This study provides a comparison for cohorts of patients with a particular disease where the EG is presumably damaged. Our findings do not entirely comply with already published data in healthy individuals.
https://pubmed.ncbi.nlm.nih.gov/31683466/

Impaired Arterial Elastic Properties and Endothelial Glycocalyx in Patients with Embolic Stroke of Undetermined Source
Thromb Haemost. 2019 Nov;119(11):1860-1868.
Conclusion: Arterial function and endothelial glycocalyx are severely impaired in ESUS (embolic stroke of undetermined source) and are linked to LA dysfunction suggesting their contribution to ESUS pathogenesis.
https://pubmed.ncbi.nlm.nih.gov/31421641/

Tie2 Activation Promotes Protection and Reconstitution of the Endothelial Glycocalyx in Human Sepsis
Thromb Haemost. 2019 Nov;119(11):1827-1838.
Conclusion: Tie2 (endothelium-stabilizing receptor) activation, but not Angpt-2 (angiopoietin-2) inhibition, initiated after septic or enzymatic damage provoked rapid refurbishment of the eGC (endothelial glycocalyx). Our data indicate that eGC breakdown in human sepsis is mediated via Tie2 deactivation by Angpt-2. Activation of Tie2 seems to accelerate recovery of the eGC and might hold promise as a therapeutic target in human sepsis.
https://pubmed.ncbi.nlm.nih.gov/31493777/

Association of sublingual microcirculation parameters and endothelial glycocalyx dimensions in resuscitated sepsis
Crit Care. 2019 Jul 24;23(1):260.
Conclusion: Our findings suggest that eGC damage can occur independently of microcirculatory impairment as measured by classical consensus parameters. Further studies in critically ill patients are needed to unravel the relationship of glycocalyx damage and microvascular impairment, as well as their prognostic and therapeutic importance in sepsis.
https://pubmed.ncbi.nlm.nih.gov/31340868/

Effects of Different Antidiabetic Medications on Endothelial Glycocalyx, Myocardial Function, and Vascular Function in Type 2 Diabetic Patients: One Year Follow-Up Study
J Clin Med. 2019 Jul 5;8(7):983.
Conclusion: Intensified glycaemic control, in addition to incretin-based treatment, improves arterial stiffness, endothelial glycocalyx, and myocardial deformation in type 2 diabetes after one year of treatment.
https://pubmed.ncbi.nlm.nih.gov/31284526/

Effects of high-intensity interval training on microvascular glycocalyx and associated microRNAs American Physiology Society / Heart and Circulatory Physiology 2019 Jun 2019
Sublingual endothelial glycocalyx and atherosclerosis. A cross-sectional study
PLoS One. 2019 Mar 27;14(3):e0213097.
Conclusion: This study evaluated the effects of physical fitness and physical exercise on microvascular parameters including glycocalyx thickness and associated miRNAs in young healthy adults. We found that maximal exercise capacity was positively associated with microvascular glycocalyx thickness at baseline. Moreover, glycocalyx thickness increased with the improvement in exercise capacity postintervention, and the increase in glycocalyx thickness was predicted by acute elevation of miRNA-143 levels. Physical activity has comprehensive health benefits and contributes to primary and secondary prevention of cardiovascular disease also by affecting the microvasculature
https://journals.physiology.org/doi/full/10.1152/ajpheart.00751.2018

Sublingual endothelial glycocalyx and atherosclerosis. A cross section study
PLoS One.2019 Mar 27;14(3):e0213097
Conclusion: Small glycocalyx size as estimated by highest PBR (perfused boundary region is associated with female sex and diabetes, which do not completely reflect a high cardiovascular risk profile. At the same time, glycocalyx size is not associated with prevalent cardiovascular disease.
https://pubmed.ncbi.nlm.nih.gov/30917159/

Early Onset Preeclampsia Is Associated With Glycocalyx Degradation and Reduced Microvascular Perfusion
J Am Heart Assoc. 2019 Feb 19;8(4):e010647.
Conclusion: Glycocalyx degradation and reduced microvascular perfusion are associated with endothelial dysfunction and activation and vascular injury in early onset preeclampsia.
https://pubmed.ncbi.nlm.nih.gov/30764695/

HDL cholesterol levels and endothelial glycocalyx integrity in treated hypertensive patients
J Clin Hypertens (Greenwich). 2018 Nov;20(11):1615-1623.
Conclusion: the authors found that BMI (β = 0.25, P = 0.006) independently predicted PBR 5-9 in the whole population. In older hypertensive patients, HDL-C ranging between 71 and 101 mg/dL might moderately protect EG and subsequently endothelial function.
https://pubmed.ncbi.nlm.nih.gov/30315671/

Inflammatory and Angiogenic Factors Linked to Longitudinal Microvascular Changes in Hemodialysis Patients Irrespective of Treatment Dose Intensity
Kidney Blood Press Res. 2017;42(5):905-918.
Conclusion: Hemodialysis intensity did not predict changes in either macro- or microvascular parameters. Inflammation mediated through the IL-8 pathway predicted microvascular injury while Flt-1, a potential marker of angiogenesis and endothelial repair, might have a significant protective role. Further understanding of these pathways will be necessary to improve dialysis outcomes.
https://pubmed.ncbi.nlm.nih.gov/29145197/

Extracellular overhydration linked with endothelial dysfunction in the context of inflammation in haemodialysis dependent chronic kidney disease
PLoS One. 2017 Aug 22;12(8):e0183281.
Conclusion: Extracellular fluid overload is significantly linked to microinflammation and markers of endothelial dysfunction. The study provides novel insight in the cardiovascular risk profile associated with overhydration in uraemia.
https://pubmed.ncbi.nlm.nih.gov/28829810/

Glycocalyx in vivo measurement
Clin Hemorheol Microcirc. 2017;67(3-4):499-503.
Conclusion: in vivo video microscopy tools technologies (e.g. Side-stream Dark Field imaging technology) allow indirect assessment of EG thickness in sublingual microcirculation by measuring the penetration extent (called Perfused Boundary Region) PBR of flowing red blood cells into the EG.
https://pubmed.ncbi.nlm.nih.gov/28922148/

P673Improvement of arterial stiffness and myocardial deformation in patients with poorly controlled diabetes mellitus type 2 after optimization of antidiabetic medication
Eur Heart J Cardiovasc Imaging. 2016 Dec 1;17(suppl_2):ii136-ii143.
Conclusion: Glycaemic control after optimizing medical treatment improves arterial stiffness, LV myocardial strain, twisting and untwisting velocity in diabetics.
https://pubmed.ncbi.nlm.nih.gov/28415103/

Perturbed mechanotransduction by endothelial surface glycocalyx modification greatly impairs the arteriogenic process
Am J Physiol Heart Circ Physiol. 2015 Aug 15;309(4):H711-7.
Conclusion: Modification of the glycocalyx by inhibition of hyaluronan synthesis renders the endothelium unresponsive to altered hemodynamic conditions resulting from femoral artery ligation, which results in a hampered restoration of distal perfusion.
https://pubmed.ncbi.nlm.nih.gov/26071545/

Effects of Glucagon-Like Peptide-1 Receptor Agonists, Sodium-Glucose Cotransporter-2 Inhibitors, and Their Combination on Endothelial Glycocalyx, Arterial Function, and Myocardial Work Index in Patients With Type 2 Diabetes Mellitus After 12-Month Treatment
Journal of the American Heart Association 2020 Apr 24
Conclusion: Twelve-month treatment with GLP-1RA (glucagon-like peptide-1 receptor agonists) , SGLT-2i (sodium-glucose cotransporter-2 inhibitors), and their combination showed a greater improvement of vascular markers and effective cardiac work than insulin treatment in type 2 diabetes mellitus. The combined therapy as second line was superior to either insulin or GLP-1RA and SGLT-2i separately.
https://www.ahajournals.org/doi/full/10.1161/JAHA.119.015716

Uncoupling of Microvascular Blood Flow and Capillary Density in Vascular Cognitive Impairment
Frontiers in Neurology 2019 Dec 3
Conclusion: Cerebral small vessel disease (cSVD) plays an important role in dementia and is a major cause for vascular cognitive impairment (VCI). Our findings suggest uncoupling of microvascular blood flow and capillary density in patients with VCI. This uncoupling may impair oxygen and nutrients exchange when blood flow increases in response to increased metabolic demand, ultimately leading to tissue damage.
https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6901497/

Derangement of the endothelial glycocalyx in sepsis
Wiley Online Library, 2018 December
Note: During the initial onset of sepsis, the glycocalyx is damaged and circulating levels of glycocalyx components, including syndecans, heparan sulfate and hyaluronic acid, can be measured and are reportedly useful as biomarkers for sepsis. Multiple factors including hypervolemia and hyperglycemia are toxic to the glycocalyx, and several agents have been proposed as therapeutic modalities, although no single treatment has been proven to be clinically effective. In this article, we review the derangement of the glycocalyx in sepsis. Despite the accumulated knowledge regarding the important roles of the glycocalyx, the relationship between derangement of the endothelial glycocalyx and severity of sepsis or disseminated intravascular coagulation has not been adequately elucidated and further work is needed.
https://onlinelibrary.wiley.com/doi/10.1111/jth.14371

Alterations of conjunctival glycocalyx and microcirculation in non-septic critically ill patients
Microvasc Res. 2018 Jul;118:44-48. doi: 10.1016/j.mvr.2018.02.004. Epub 2018 Feb 17.
Conclusion: In non-septic ICU patients we observed signs of conjunctival microvascular glycocalyx degradation. Conjunctival microcirculatory perfusion abnormalities were present in patients with cerebral pathology, whereas sublingual microvascular alterations occured during systemic endothelial damage. Alternatively, syndecan-1 levels during cerebral pathology were simply not high enough to provoke sublingual microvascular alterations. These results merit further investigation.
https://microvascular.com/wp-content/uploads/2019/05/Paper_01_Boerma_2018.pdf

Automated Measurement of Microvascular Function Reveals Dysfunction in Systemic Sclerosis: A Cross-sectional Study.
J Rheumatol. 2017 Nov;44(11):1603-1611. doi: 10.3899/jrheum.170120. Epub 2017 Sep 15.
Conclusion: Glycocalyx barrier function in SSc. In our present study, we have found a higher PBR in patients with SSc compared with controls, suggestive of impaired endothelial glycocalyx barrier function.
https://microvascular.com/wp-content/uploads/2019/05/Paper_02_1603.full_.pdf

Advanced age results in a diminished endothelial glycocalyx.
Am J Physiol Heart Circ Physiol. 2018 Sep 1;315(3):H531-H539. doi: 10.1152/ajpheart.00104.2018. Epub 2018 May 11.
Conclusion: these findings indicate that aging is associated with significant glycocalyx deterioration that is accompanied by markers of impaired microvascular perfusion that may be influenced by age-related alterations in hyaluronan synthesis.
https://microvascular.com/wp-content/uploads/2019/05/Paper_03_Donato_2018.pdf

Induced Trf2 deletion leads to aging vascular phenotype in mice associated with arterial telomere uncapping, senescence signaling, and oxidative stress.
J Mol Cell Cardiol. 2019 Feb;127:74-82. doi: 10.1016/j.yjmcc.2018.11.014. Epub 2018 Nov 29.
Note: endothelial glycocalyx dysfunction can independently mediate blood pressure dysregulation by disrupting sodium resorption through the microvascular endothelium.
https://microvascular.com/wp-content/uploads/2019/05/Paper_04_Donato_2018b.pdf

Impact of Intravenous Fluid Challenge Infusion Time on Macrocirculation and Endothelial Glycocalyx in Surgical and Critically Ill Patients.
Biomed Res Int. 2018 Nov 1;2018:8925345. doi: 10.1155/2018/8925345. eCollection 2018.
Discussion: In our trial, fluid administration in form of fluid challenge increased the PBR value independently of the infusion time. However, there may be a weak signal that septic fluid responders seem to be more affected.
https://microvascular.com/wp-content/uploads/2019/05/Paper_05_Cerny_2018-1.pdf

Neuraxial anesthesia is less harmful to the endothelial glycocalyx during elective joint surgery compared to general anesthesia1,2.
Clin Hemorheol Microcirc. 2018 Nov 29. doi: 10.3233/CH-180428. [Epub ahead of print]
Discussion: Our study showed that elective joint surgery led to increased PBR dimensions and that patients in 174 GA group had higher PBR 2 hours after surgery compared to NA group.
https://microvascular.com/wp-content/uploads/2019/05/Paper_06_Cerny_2018b.pdf

Effect of acute hypernatremia induced by hypertonic saline administration on endothelial glycocalyx in rabbits.
Clin Hemorheol Microcirc. 2018 Nov 2. doi: 10.3233/CH-189907. [Epub ahead of print]
Conclusion: acute hypernatremia induced by administration of hypertonic saline was associated with an increased value of PBR in the sublingual microcirculation. Increased PBR values during hypernatremia were not accompanied by increased levels of plasma syndecan-1, suggesting transient and rather functional effects of hypernatremia on PBR in contrast to direct and structural EG damage.
https://microvascular.com/wp-content/uploads/2019/05/Paper_07_Cerny_2018c.pdf

The Effect of Fluid Loading and Hypertonic Saline Solution on Cortical Cerebral Microcirculation and Glycocalyx Integrity.
J Neurosurg Anesthesiol. 2018 Jul 13. doi: 10.1097/ANA.0000000000000528. [Epub ahead of print]
Conclusion: Liberal fluid loading was associated with altered cortical cerebral microcirculation and EG integrity parameters. The 3.2% saline treatment did not affect cortical cerebral microcirculation or EG integrity markers.
https://microvascular.com/wp-content/uploads/2019/05/Paper_08_Cerny_2018d.pdf

Increase in perfused boundary region of endothelial glycocalyx is associated with higher prevalence of ischemic heart disease and lesions of microcirculation and vascular wall.
Microcirculation. 2018 May;25(4):e12454. doi: 10.1111/micc.12454.
Conclusion: PBR can be potentially used as a highly reproducible (CV <10%) non- invasive marker for assessment of cardiovascular risks in complex with other known biomarkers.
https://microvascular.com/wp-content/uploads/2019/05/Paper_09_Gorshkov_2018.pdf

In vivo assessment of the human cerebral microcirculation and its glycocalyx: A technical report.
J Neurosci Methods. 2018 Jun 1;303:114-125. doi: 10.1016/j.jneumeth.2018.03.009. Epub 2018 Mar 22.
Conclusion: This is the first report on the in vivo assessment of the human cerebrovascular glycocalyx. SDF imaging is a safe, quick, and straightforward technique to evaluate the cerebral microcirculation and its glycocalyx. Since the cerebral microcirculation and its glycocalyx play an eminent role in neurovascular coupling and accommodating cerebral homeostasis, this method may significantly advance research on the pathophysiology of various neurological disorders.
https://microvascular.com/wp-content/uploads/2019/05/Paper_10_Haeren_2018.pdf

HDL cholesterol levels and endothelial glycocalyx integrity in treated hypertensive patients.
J Clin Hypertens (Greenwich). 2018 Nov;20(11):1615-1623. doi: 10.1111/jch.13404. Epub 2018 Oct 13.
Conclusion: in hypertensive patients, older than 50 years, HDL-C ranging between 71 and 101 mg/dL might moderately pro- tect EG and subsequently endothelial function. Future studies in several groups of low- or high-risk hypertensive patients are needed in order to evaluate the beneficial role of extremely elevated HDL-C regarding cardiovascular risk as well as the EG as a novel index of target organ damage in essential hypertension.
https://microvascular.com/wp-content/uploads/2019/05/Paper_11_Ikonomidis_2018.pdf

Association of impaired endothelial glycocalyx with arterial stiffness, coronary microcirculatory dysfunction, and abnormal myocardial deformation in untreated hypertensives.
J Clin Hypertens (Greenwich). 2018 Apr;20(4):672-679. doi: 10.1111/jch.13236. Epub 2018 Mar 2.
Conclusion: Endothelial glycocalyx is damaged in newly diagnosed untreated hypertensives. This damage is related to abnormal aortic elastic properties and to impaired coronary microcirculatory function and contributes to impaired LV (left ventricular) longitudinal deformation.
https://microvascular.com/wp-content/uploads/2019/05/Paper_12_Ikonomidis_2018b.pdf

Sublingual functional capillary rarefaction in chronic heart failure.
Eur J Clin Invest. 2018 Feb;48(2). doi: 10.1111/eci.12869. Epub 2017 Dec 14.
Conclusion: CHF (chronic heart failure) patients have got a markedly lower functional and total perfused capillary density in sublingual microvasculature when compared to controls, indicating a systemic decrease in microcirculation.
https://microvascular.com/wp-content/uploads/2019/05/Paper_13_Jilma_2018.pdf

Bedside analysis of the sublingual microvascular glycocalyx in the emergency room and intensive care unit - the GlycoNurse study.
Scand J Trauma Resusc Emerg Med. 2018 Feb 14;26(1):16. doi: 10.1186/s13049-018-0483-4.
Conclusion: : Glycocalyx dimensions can be measured at patients' bedside precisely by non-invasive assessment of the PBR. This assessment could become part of standard monitoring and contribute to clinical decision-making and resuscitation protocols in clinical trials and daily practice.
https://microvascular.com/wp-content/uploads/2019/05/Paper_14_Kuempers_2018.pdf

Acute ischemic injury to the renal microvasculature in human kidney transplantation.
Am J Physiol Renal Physiol. 2010 Nov;299(5):F1134-40
Conclusion: We conclude that renal ischemia and reperfusion is associated with reduced capillary blood flow and loss of glycocalyx integrity. These findings form the basis for development of novel interventions to prevent ischemic acute kidney injury.
https://pubmed.ncbi.nlm.nih.gov/20810613/

Effect of sulodexide on endothelial glycocalyx and vascular permeability in patients with type 2 diabetes mellitus.
Diabetologia. 2010 Dec;53(12):2646-55
Conclusion: Type 2 diabetes is associated with glycocalyx perturbation and increased vascular permeability, which are partially restored following sulodexide administration. Further studies are warranted to determine whether long-term treatment with sulodexide has a beneficial effect on cardiovascular risk. Sulodexide is a drug used to treat chronic venous ulcers in the leg.
https://pubmed.ncbi.nlm.nih.gov/20865240/

Methods for evaluating endothelial function: a position statement from the European Society of Cardiology Working Group on Peripheral Circulation.
Eur J Cardiovasc PrevRehabil. 2011 Dec;18(6):775-89
Conclusion: The ability of these methods to detect endothelial dysfunction before overt cardiovascular disease manifests make them attractive clinical tools for prevention and rehabilitation.
https://pubmed.ncbi.nlm.nih.gov/21450600/

Damage of the endothelial glycocalyx in dialysis patients.
J Am SocNephrol. 2012 Nov;23(11):1900-8
Conclusion: these data suggest that dialysis patients have an impaired glycocalyx barrier and shed its constituents into blood, likely contributing to the sustained endothelial cell activation observed in ESRD (end stage renal disease).
https://pubmed.ncbi.nlm.nih.gov/23085635/

Sublingual microvascular glycocalyx dimensions in lacunar stroke patients.
Cerebrovasc Dis. 2013;35(5):451-4
Conclusion: White matter lesions are associated with an increase in the red blood cell permeable part of the sublingual microvascular glycocalyx in lacunar stroke patients. This implicates compromised glycocalyx barrier properties, which is consistent with impaired endothelial function in lacunar stroke patients with white matter lesions.
https://pubmed.ncbi.nlm.nih.gov/23735841/

Non-invasive assessment of microvascular dysfunction in families with premature coronary artery disease.
Int J Cardiol. 2013 Oct 12;168(5):5026-8
Conclusion: *No abstract available*
https://pubmed.ncbi.nlm.nih.gov/23968713/

Alteration of the sublingual microvascular glycocalyx in critically ill patients.
Microvasc Res. 2013 Nov;90:86-9
Conclusion: A weak positive correlation was found between PBR and heart rate (r=0.3, p=0.03). In 17 septic patients, a correlation was found between PBR and number of rolling leukocytes in post-capillary venules (RL/venule) (r=0.55, p=0.02), confirming that glycocalyx shedding enhances leukocyte-endothelium interaction.
https://pubmed.ncbi.nlm.nih.gov/23988876/

Association of kidney function with changes in the endothelial surface layer.
Clin J Am SocNephrol. 2014 Apr;9(4):698-704
Conclusion: Reduced renal function is strongly associated with low endothelial surface layer dimensions. After successful kidney transplantation, the endothelial surface layer is indistinguishable from control.
https://pubmed.ncbi.nlm.nih.gov/24458084/

Microcirculatory effects of the transfusion of leukodepleted or non-leukodepleted red blood cells in patients with sepsis: a pilot study.
Crit Care. 2014 Feb 17;18(1):R33
Conclusion: This study does not show a clear superiority of leukodepleted over non-leukodepleted RBC transfusions on microvascular perfusion in patients with sepsis, although it suggests a more favorable effect of leukodepleted RBCs on microcirculatory convective flow. Further studies are needed to confirm these findings.
https://pubmed.ncbi.nlm.nih.gov/24528648/

Skeletal muscle capillary density and microvascular function are compromised with aging and type 2 diabetes.
J ApplPhysiol (1985). 2014 Apr 15;116(8):998-1005Â
Conclusion: Sidestream darkfield imaging showed a significantly greater thickness of the erythrocyte perfused boundary region in the type 2 diabetic patients compared with the young. Skeletal muscle capillary density is reduced with aging and type 2 diabetes and accompanied by impairments in endothelial glycocalyx function, which is indicative of compromised vascular function.
https://pubmed.ncbi.nlm.nih.gov/24577061/

Deeper penetration of erythrocytes into the endothelial glycocalyx is associated with impaired microvascular perfusion.
PLoS One. 2014 May 9;9(5):e96477
Conclusion: The microvascular beds with a thick ("healthy") glycocalyx (low PBR), reflects efficient perfusion of the microvascular bed. In contrast, a thin ("risk") glycocalyx (high PBR) is associated with a less efficient and defective microvascular perfusion.
https://pubmed.ncbi.nlm.nih.gov/24816787/

Is the systemic microvascular endothelial glycocalyx in peritoneal dialysis patients related to peritoneal transport?
Nephron ClinPract. 2014;128(1-2):159-65
Conclusion: No relationships are present between the systemic endothelial glycocalyx, which was assessed by SDF (sidestream darkfield imaging), and peritoneal transport. In nonfast transporters, a reduction in blood vessel density caused by endothelial glycocalyx alterations or a thicker permeable phase of the glycocalyx delaying the access of small solutes to the small pores may be important. .
https://pubmed.ncbi.nlm.nih.gov/25376179/

Effects of ultrapure hemodialysis and low molecular weight heparin on the endothelial surface layer.
Blood Purif. 2014;38(3-4):203-10
Conclusion: HD (hemodialysis) caused a significant increase in Syndecan-1 without a change in PBR. The administration of LMWH appeared to precede the rise in Syndecan-1. Syndecan-1 protein functions as an integral membrane protein and participates in cell proliferation, cell migration, and cell matrix interactions via its receptor for extracellular matrix proteins.
https://pubmed.ncbi.nlm.nih.gov/25531879/

Characteristics and determinants of the sublingual microcirculation in populations of different ethnicity.
Hypertension. 2015 May;65(5):993-1001
Conclusion: a higher cardiovascular risk profile is associated with functional recruitment of capillaries with preserved glycocalyx that protects the endothelial lining.
https://pubmed.ncbi.nlm.nih.gov/25712718/

Plasma free hemoglobin and microcirculatory response to fresh or old blood transfusions in sepsis.
PLoS One. 2015 May 1;10(5):e0122655
Conclusion: Old RBC transfusion was associated with an increase in plasma fHb (free hemoglobin) in septic patients. Increasing plasma fHb levels were associated with decreased microvascular density.
https://pubmed.ncbi.nlm.nih.gov/25932999/

Effect of an acute and chronic slat load on microvascular permeability in healthy subjects.
JHypertens. 2015 Jun;33 Suppl 1
Conclusion: Acute, but not chronic Na+ (sodium) loading in healthy subjects resulted in higher microvascular permeability that coincided with increased plasma volume. These results suggest that deleterious microvascular effects of an acute Na+ load may develop by hydrostatic, or hypertonic, or direct effects of Na+ to the endothelium.
https://journals.lww.com/jhypertension/Abstract/2015/06001/7D_06__EFFECTS_OF_AN_ACUTE_AND_CHRONIC_SALT_LOAD.273.aspx

Perturbation of the microvascular glycocalyx and perfusion in infants after cardiopulmonary bypass.
J Thorac Cardiovasc Surg. 2015 Dec;150(6):1474-81.
Conclusion: Our study reveals for the first time local perturbations of the endothelial glycocalyx and microvascular perfusion in infants after surgery with cardiopulmonary bypass. Microcirculatory monitoring might be a useful tool to evaluate interventions aiming at reduction of bypass-related complications.
https://pubmed.ncbi.nlm.nih.gov/26395044/

Side-by-Side Alterations in Glycocalyx Thickness and Perfused Microvascular Density During Acute Microcirculatory Alterations in Cardiac Surgery.
Microcirculation. 2016 Jan;23(1):69-74.
Conclusion: This study shows that endothelial glycocalyx dimensions decrease after onset of CPB (cardiopulmonary bypass) and are closely related to microvascular perfusion when assessed with a novel, noninvasive technique.
https://pubmed.ncbi.nlm.nih.gov/26638697/

The impact of periodontal disease treatment on endothelium of sublingual microvessels.
Stomatologiia (Mosk). 2016;95(4):9-12. Russian.
Conclusion: In both groups the changes of parameters of endothelial glycocalyx (EGC) in the early stages of treatment were not significant. In long terms the changes were not revealed in group 1, but in group 2, 6 months after surgical treatment in all patients the decrease in the thickness of the permeable glycocalyx decreased and increase of the volume of red blood cells filling was observed. Group 1: received only local anti-inflammatory therapy. Group 2: underwent surgical intervention on the periodontium in addition to local anti-inflammatory therapy.
https://pubmed.ncbi.nlm.nih.gov/27636753/

Protocol for intraoperative assessment of the human cerebrovascular glycocalyx.
BMJ Open. 2017 Jan 5;7(1)
Anaylsis: This protocol is designed as a prospective observational case-control study in patients who undergo resective brain surgery as treatment for TLE. Control subjects are patients without a history of epileptic seizures, who undergo a craniotomy or burr hole surgery for other indications. Intraoperative glycocalyx thickness measurements of sublingual, cortical and hippocampal microcirculation are performed by video microscopy using sidestream dark-field imaging. Demographic details, seizure characteristics, epilepsy risk factors, intraoperative haemodynamic parameters and histopathological evaluation are additionally recorded.
Ethics: This protocol has been ethically approved by the local medical ethical committee (ID: NL51594.068.14) and complies with the Declaration of Helsinki and principles of Good Clinical Practice. Informed consent is obtained before study enrolment and only coded data will be stored in a secured database, enabling an audit trail. Results will be submitted to international peer-reviewed journals and presented at international conferences.
https://pubmed.ncbi.nlm.nih.gov/28057660/

Early detection of left ventricular dysfunction in first-degree relatives of diabetic patients by myocardial deformation imaging: The role of endothelial glycocalyx damage.
Int J Cardiol. 2017 Apr 15;233:105-112.
Conclusion: First-degree relatives and dysglycaemics (refers to blood sugar levels that go too low or too high) have reduced glycocalyx thickness related with impaired LV (left ventricle) longitudinal, twisting-untwisting function. Postprandial hyperglycemia when combined with insulin resistance causes LV longitudinal dysfunction leading to increased LV twisting.
https://pubmed.ncbi.nlm.nih.gov/28096045/

Improvement of arterial stiffness and myocardial deformation in patients with poorly controlled diabetes mellitus type 2 after optimization of antidiabetic medication.
Eur Heart J Cardiovasc Imaging. 2016 Dec 1;17(suppl_2)
Conclusion: Glycaemic control after optimizing medical treatment improves arterial stiffness, LV (left ventricle) myocardial strain, twisting and untwisting velocity in diabetics.
https://pubmed.ncbi.nlm.nih.gov/28415103/

Effects of varenicline and nicotine replacement therapy on arterial elasticity, endothelial glycocalyx and oxidative stress during a 3-month smoking cessation program.
Atherosclerosis. 2017 May 13;262:123-130.
Conclusion: A smoking cessation program using varenicline (trade name Chantix) or NRT (nicotine replacement treatment) for 3 months resulted in a decrease of CO (exhaled), oxidative stress, arterial stiffness and restored endothelial glycocalyx. These effects were more evident after varenicline treatment, likely because of a greater CO reduction, and were maintained after 1 year only in subjects who abstained from smoking.
https://pubmed.ncbi.nlm.nih.gov/28549278/

Non-invasive assessment of microvascular dysfunction in patients with microvascular angina.
Int J Cardiol. 2017 Dec 1;248:433-439. doi: 10.1016/j.ijcard.2017.05.010. Epub 2017 Jul 18.
Conclusion: Patients with MVA (microvascular angina) can be characterized by microvascular glycocalyx dysfunction using sublingual microscopy. The strong correlation between sublingual PBR responsiveness and myocardial perfusion reserve suggests that the glycocalyx may play an important role in the regulation of microvascular volume for myocardial perfusion and supports the concept of impaired glycocalyx barrier properties in MVA.
https://pubmed.ncbi.nlm.nih.gov/28733074/

The Measurement of the Endothelial Glycocalyx as a New Biomarker of Endothelial Derangement in Systemic Sclerosis: A Challenge for the Future.
J Rheumatol. 2017 Nov;44(11):1572-1574. doi: 10.3899/jrheum.170958. Epub 2017 Nov 1. No abstract available.
No abstract available
https://pubmed.ncbi.nlm.nih.gov/29093075/