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REVIEW

Vascular Health Promotion Project and Vascular Medicine in China-CCVM2004-2023

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Abstract: Cardiovascular disease(CVD) has become a major disease burden affecting people's health in China. Blood vessels are very important for human health and are the "sentinel" for the development of many cardiovascular and cerebrovascular diseases. The key to effectively preventing fatal, disabling heart, brain and peripheral vascular events lies in controlling traditional and non-traditional risk factors for vascular health from the source, and early assessment and intervention of early vascular lesions. Since 2004, China government promoted the early detection technology of vascular lesions and vascular medicine, and proposed the Beijing Vascular Health Stratification (BVHS) to provide suggestions for the examination, evaluation and management of risk factors, and to provide new ideas for lifelong maintenance of vascular health. This review mainly introduces the establishment and development of the clinical discipline of "vascular medicine" in the past 20 years in China, introduces the indicators for detecting vascular function and structure and the predictive value of vascular events, and carries out intelligent and digital management of vascular health throughout the life cycle of individualized prevention, treatment and rehabilitation for people with different parts or degrees of lesions, effectively reducing the occurrence and development of cardiovascular and cerebrovascular diseases, and the prospect of new technology in maintaining vascular health.

Keywords: heart and vascular health, vascular medicine, early assessment, digital, Beijing vascular health stratification

Introduction

Cardiovascular and cerebrovascular diseases are one of the most serious diseases threatening human health in the world, and the pathophysiological basis is vascular lesions, then the maintenance of vascular health is extremely important. In the past 20 years, with the promotion of appropriate technologies for the early detection of vascular diseases, the exploration of comprehensive management models of vascular diseases, and the development of professional disciplines in vascular medicine, a group of medical and health institutions represented by Peking University Shougang Hospital have gradually explored the characteristic cardiovascular and cerebrovascular diseases prevention and treatment model of the whole life cycle of management with vascular health as the core, closely uniting secondary and tertiary hospitals, community health service centers, and family doctors. It has realized the "threshold forward" and "sinking the center of gravity" in the prevention and treatment of chronic diseases, and has made positive contributions to reducing the mortality and disability rate of cardiovascular and cerebrovascular diseases.

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Vascular Health Promotion Project in China

The China International Congress of Vascular Medicine(CCVM), the first Chinese Heart and Vascular Health Promotion Program (CHVHPP) Promotion Conference, has been held since 2004, originally named the Chinese Conference on Vascular Disease and Arterial Function, which is the first international academic conference on early stage of vascular lesions and vascular health maintenance, vascular risk factor identification and intervention, vascular biology, vascular disease medical surgery and interventional treatment, vascular disease rehabilitation and other comprehensive contents. Since 2006, the Asia-Pacific Congress of Vascular Medicine has been held during the CCVM, and the CCVM has become international.[1,2] In 2010, the first vascular medicine center in China, the Vascular Medicine Center of Peking University Shougang Hospital, was established, aiming to explore the prevention and treatment mode of vascular diseases. In 2011, vascular medicine was opened as an elective course at Peking University Health Science Center. In 2012, the Blue Book on the Development of Vascular Medicine in China was officially released. In 2014, vascular medicine was opened as a public elective course at Peking University, and vascular medicine entered the public university lecture hall as a new discipline. In December 2014, the establishment of the Vascular Medicine Professional Committee of the China Medical Education Association, the first second-level academic organization specializing in vascular medicine in China, marked that vascular medicine is not only a new field of medical clinical practice, but also enters the track of standardized construction.

In the past 20 years, with the promotion of appropriate technologies for the early detection of vascular diseases, the exploration of comprehensive management models of vascular diseases, and the development of professional disciplines in vascular medicine, a group of medical and health institutions represented by Peking University Shougang Hospital have gradually explored the characteristic cardiovascular and cerebrovascular disease prevention and treatment mode of life cycle vascular health management with vascular health as the core, and closely united with tertiary hospitals, secondary hospitals, community health service centers, and family doctors to achieve the "threshold forward" and "sinking the center of gravity" of chronic disease prevention and treatment. It has made positive contributions to reducing the mortality rate and disability rate of cardiovascular and cerebrovascular diseases.

Since 1997, China began to carry out vascular function research, and with the support of the Ministry of Health, carried out the promotion of "Centennial Plan" "early detection technology of vascular lesions", with the development of promotion, clinical and scientific research, gradually formed the prototype of vascular medicine. In 2006, he put forward the methodological concept of the early detection technology system of vascular disease as the basis for the prevention and treatment of systemic vascular disease, began to explore the management concept of systemic vascular disease, took the lead in proposing the "Application Guide of Early Detection Technology of Vascular Lesions" in China, and established the first early detection company for vascular and heart diseases in April 2010. Comprehensive Prevention and Treatment Center for Early Prevention and Early Treatment: The Vascular Medicine Center of Peking University Shougang Hospital integrates medical treatment, scientific research, teaching, prevention, and academic exchanges at home and abroad, and is the vanguard of promoting the construction of professional disciplines in vascular medicine. In 2015, the BVHS system was proposed, creating a model of transformation from "disease treatment" to "health management" characterized by vascular health system assessment and full life cycle management.

In 2017, it undertook the key special project of the national key R&D plan "Digital Diagnosis and Treatment Equipment Research and Development": "High Credibility and Strong Intelligence Diagnosis and Treatment Service Model Solution for Cardiovascular and Cerebrovascular Diseases", and opened the research and application of artificial intelligence(AI)-assisted three-level diagnosis and treatment of cardiovascular and cerebrovascular diseases - Shougang Vascular Management Model. In 2019, the Vascular Health Research Center of Peking University Health Science Center was established, the first China Intelligent Digital Heart and Vascular Health Integrated Traditional Chinese and Western Medicine Management Forum was held in Xindu District, Chengdu in 2021, and the second forum was held in Gucheng Community Health Service Center in 2022 to explore the frontier cross-technology fields of applied medicine, especially the fields of AI, machine learning and deep learning, to strengthen clinical disease diagnosis and treatment decisions, and promote the integration, reform and innovation of the whole life cycle management of Chinese and Western medicine healthy heart and vascular health. Ultimately building the future of medicine.

In March 2023, the National Research Institute of Health and Medical Big Data of Peking University established the Intelligent Heart and Vascular Health Digital Management Research Center, which will rely on the superior Shougang population data resources to analyze and research, explore intelligent and digital management in the field of vascular diseases, and the management mode of the whole life cycle, which is of great significance for reducing the increasingly heavy medical burden of CVDs in the country and Beijing and improving the quality of national health.

In 2023, the practice guidelines for digital management of the whole life cycle of intelligent vascular health in China (the first report in 2022) were released,[3] which pointed out that digitalization, smart medical care and deep learning processes have greatly improved the prospects for the prevention of vascular diseases. Based on traditional risk factors, non-traditional risk factors,[4] clinical and laboratory tests, imaging data, wearable devices, induction data and bionomics, today's vascular health service system will be reconstructed in the future, patients will obtain maximum benefits, and the digital smart health road will reshape the prevention model of vascular diseases. Therefore, the launch of the national digital vascular medical center construction project is of great significance.

In the future, through AI, the Internet and new 5G technology to support the maintenance of vascular health and ultimately reduce the incidence of CVD, comprehensively evaluate the individual's vascular health classification, and formulate individualized prevention, treatment and rehabilitation strategies combining traditional Chinese and Western medicine. The early comprehensive maintenance of vascular health provides new ideas and new means for the early prevention and treatment of chronic diseases, helping to achieve the national strategic goal of "Healthy China".

Vascular medicine establishes the concept of "vascular tree", vascular medicine is based on blood vessels, human blood vessels as a whole, research on diseases of organs and systems such as the heart, brain, kidney, lung, intestine, peripheral blood vessels, including early detection, intervention and rehabilitation of vascular diseases. Vascular medicine is a new interdisciplinary clinical discipline integrating cardiology, neuroscience, endocrinology, nephrology, coronary surgery, vascular surgery, vascular biomechanics, health education and genetics. The most striking feature of vascular medicine is its distinctive translational properties. The concept of vascular medicine is actually advocating the establishment of a new model of vascular disease health management, abandoning the traditional "headache and foot pain", treating the important organs of the whole body as a whole, comprehensively evaluating the health status of the blood vessels they supply, and guiding medical staff to adopt early intervention strategies including lifestyle improvement, drugs, surgery or intervention, and early detection, prevention and even reversal of adverse vascular events.

Vascular Assessment Indicators in Clinical Practice

Vascular Endothelial Function Assessment

Coronary endothelial function assessment is the gold standard for endothelial function testing using coronary angiography, where drugs such as acetylcholine are injected into the coronary arteries to induce coronary vasoconstriction. Ultrasound testing of brachial artery flow-mediated vasodilation (FMD) is the most effective noninvasive assessment of endothelial function method, normal value is FMD >10%.[5] Post-exercise reduction of brachial FMD > 1.3% is predictive for cardiovascular events in patients with intermittent claudication.[6] FMD may simply reflect compound risk burden that impacts upon vessel function and hence may not provide incremental risk prediction. FMD examination is highly dependent on the skill level of the tester, FMD results are influenced by cuff position, and there is a lack of uniform guideline standards for laboratory testing.[7] The reactive hyperemia index (RHI) test reflects the microcirculatory function and endothelial function of small blood vessels throughout the body, RHI is a predictor for assessing acute coronary syndromes bleeding and cardiovascular death[8,9] Reduced RHI is associated with an increased risk of adverse clinical outcomes in Heart Failure.[10] RHI values correlate with CHA2DS2-VASc scores, Assessing the endothelial function could enable the risk stratification of cardiovascular events after AF ablation.[11] An 18-month follow-up study of patients with unstable angina pectoris and type 2 diabetes mellitus (T2DM) found that a decrease in peripheral RHI was associated with adverse cardiovascular events.[12] PAT also suffers from defects, such as blood flow to the peripheral vascular bed affected by autonomic tone and environment, and sensitivity to probe movement may lead to errors.The finger detection device uses disposable finger sleeves, which is slightly more expensive for clinical and research purposes.

Ultrasound Techniques to Assess Arterial Structural and Functional Abnormalities

Comprehensive screening of cervical vascular ultrasound is the most important basis for early diagnosis of systemic atherosclerosis. Carotid intima-media thickness (cIMT) is closely related to CVD, and higher than the normal value in this age group is judged to be endo-medial membrane thickening.[13] Near and far wall common carotid artery-IMT values were approximately linearly associated with CVD risk.[14] CIMT progression as surrogate marker for cardiovascular risk, and the extent of intervention effects on cIMT progression predicted the degree of CVD risk reduction.[15] The presence of a heterogeneous carotid plaque in patients who underwent PCI predicted future CV events. These patients may require more aggressive medical therapy and careful follow-up.[16] Criteria for determining arteriosclerotic plaque: both longitudinal and cross-sectional scans of blood vessels show the presence of echoic structures protruding into the lumen, or abnormal blood defects protruding into the lumen, or local cIMT exceeding 50% of the adjacent median-medial membrane thickness. Routine subclavian artery detection can effectively improve the detection rate of early atherosclerosis, which greatly helps the diagnosis of early atherosclerosis. Ultrasound of the abdominal aorta, renal artery, and lower extremity arteries can also detect stenosis and occlusion.

Evaluation of Arteriosclerosis

Arterial stiffness depends primarily on the functional status of the aortic and is a risk factor for CVD progression and an independent predictor of all-cause mortality. Arteriosclerosis detection can be detected by non-invasive arteriosclerosis detection equipment, which is easy to conduct census in community medical institutions. PWV is a common measure of arterial stiffness. Among them, carotid-femoral pulse wave velocity (CF-PWV) detection is currently considered to be the gold standard for the hardness assessment of large dynamic prices. Normal values: CF-PWV≤9 m/s, brachial PWV ≤14 m/s.[17] IMT and brachial artery PWV, especially when combined, are useful in predicting future vascular events in elderly subjects.[18] There is a correlation between CF-PWV and biomarkers such as NT-proBNP, Hcy, and urine albumin (microalbumin).[19] Especially in older adults without CVD, CF-PWV is strongly associated with the development of coronary heart disease and heart failure.[20] In cohort studies of the relative contribution of pulse pressure and arterial stiffness to CVD, pulse pressure-arterial stiffness mismatch is common in the community. CF-PWV may modify the association of CPP with CVD risk, with the greatest risk being observed in those with elevated CPP and CF-PWV.[21] The cardio ankle vascular index(CAVI) test is a new assessment of arterial stiffness derived from the stiffness factor Que and is related to arterial stiffness and compliance. CAVI is a marker of Vascular health (VH) associated with arterial damage in patients with hypertension, diabetes, metabolic syndrome, and dyslipidemia.[22–25] CAVI was developed to reflect the stiffness of the arterial tree from the beginning of the aorta to the ankle, which is not affected by blood pressure immediately at the time of measurement, is reproducible, and can be used to assess the severity of CVD and its risk.[26] CAVI may have higher discrimination in all-cause mortality and major adverse cardiovascular endpoints.[27] CAVI is a more stable indicator, CAVI has the advantages of non-invasive, immune to blood pressure, and inexpensive. Generally, arteriosclerosis detectors can measure CAVI and ankle brachial index(ABI), and can be considered for large-scale vascular screening in the future. Central artery pressure can be obtained by invasive cardiac catheterization and noninvasive radial or carotid artery tone testing, reflecting the stiffness of the aorta, and central artery pressure predicting cardiovascular events in the elderly population.

ABI Detection

Post-exercise ABI should be measured in patients with normal or low resting ABI and clinical suspicion of LEAD.[28] An ABI ≤ of 0.9 or ≥1.3 should be considered an increased risk of cardiovascular events or death, regardless of LEAD symptoms or other cardiovascular risk factors. Among patients with nonembolic ischemic stroke or transient ischemic attack, those with low ABI had a higher rate of vascular events and death in this population. Screening for ABI in stroke patients may help identify patients at high risk of future events.[29] In studies of black adults, lower extremity symptoms and ankle-brachial index screening were found to be predictors of cardiovascular outcomes.[30]

Radial Pulse Wave Analysis

Radial pulse measurement and analysis can measure central aortic pressure, pressure wave enhancement index, and aortic and arteriole elasticity, all of which reflect the compliance of systemic vessels. Impaired arterial elasticity predicts cardiovascular morbidity and mortality, and there is a strong and independent association between small artery elasticity and CVD in men. In postmenopausal women, similar trends and effect sizes were observed.[31] The first harmonic of radial pulse wave predicts major adverse cardiovascular and microvascular events in patients with type 2 diabetes.[32]

Biomarker Detection of Vascular Aging and Endothelial Dysfunction

Including blood lipids, blood sugar, homocysteine, hypersensitivity C-reactive protein, uric acid, brain natriuretic peptide, D-dimer, albumin (ALB) and glycated hemoglobin. Patients with hypertension, diabetes, coronary heart disease (CHD), and LEAD have higher CAVI levels and are associated with lipid levels, homocysteine, hypersensitivity C-reactive protein, uric acid, and brain natriuretic peptide.[33,34] Homocysteine as a predictor and prognostic marker of atherosclerotic CVD.[35] In people without CVD, risk assessment with hypersensitivity C-reactive protein or fibrinogen can help prevent cardiovascular events. There is evidence to support the role of ALB as a strong predictor of cardiovascular risk. According to several cohort studies and meta-analyses, hypoalbuminaemia is a strong predictor of all-cause and cardiovascular mortality in hospitalized and non-hospitalized patients with or without comorbidities.[36] In prospective cohorts, BUN was assessed for risk of CHD and elevated BUN levels may be associated with an increased risk of coronary heart disease.[37] HbA1c has been recognized as a predictor of cardiovascular events.[38] There is a sustained relationship between HbA1c and CHD risk, even below the diagnostic threshold for diabetes.[39] Novel stratification of lipid risk, simply using triglyceride and non-high-density lipoprotein cholesterol levels, combined with FMD measurement, is useful for predicting cardiovascular outcomes in patients with coronary artery disease.[40] The detection of lipoprotein (a), nanoscale selenium, Human umbilical vein endothelial cells, and miR-145 indicators can be used as a new strategy for the treatment of vascular dysfunction.[41]

Testing for Atherosclerosis

CTA/MRA/DSA/MRI High classification intracranial/External vessel wall imaging) shows changes of cerebral Atherosclerosis.[42] Coronary angiography (CAG): the gold standard for pre-diagnosis of coronary artery narrowing. High-risk plaque features and plaque burden at coronary CT angiography were associated with cardiovascular events.[43] Left atrial function by cardiac computed tomography is a predictor of heart failure and cardiovascular death.[44] Intravascular ultrasound (IVUS): higher sensitivity than CAG, which has certain advantages in judging whether plaque is stable; A meta-study evaluating the association between coronary plaque regression and MACE by intravascular ultrasound (IVUS) found that regression of atherosclerotic plaque by 1% was associated with a 25% reduction in the odds of MACEs.[45] Optical coherence tomography (OCT): more accurately reflects heavy conditions than IVUS, allowing more accurate detection and classification of plaques; Multimodal IVUS+OCT images accurately and efficiently predict plaque cap thickness and stress/strain index changes, which are essential for the assessment and prediction of the risk of fragile plaque progression and rupture, and for the diagnosis, management and treatment of CVD and the prevention of cardiovascular events.[46] Multi-layer spiral computed tomography (MSCT): screening for vulnerable plaques; MRI: dynamic observation of plaques multiple times in a row. Nuclide scintigraphy: there is a certain prospect in judging whether the plaque is stable; Vascular endoscopy: direct visualization of the surface of the plaque and the structure in the lumen.

Beijing Vascular Health Stratification(BVHS) Comprehensive Evaluation System

Based on traditional risk factors, BVHS superimposed comprehensive evaluation indicators of vascular structure and function, including non-invasive determination of vascular endothelial function and arterial valence hardness. BVHS integrates different assessment and grading strategies from vascular function to structure, from early to late disease, and individualized intervention and management for people at different levels. A cross-sectional study evaluating the

correlation between cerebral white matter lesions and arteriosclerosis in 1176 adults using the Heart Ankle Vascular Index found that higher arterial stiffness evaluated using the Heart Ankle Vascular Index was associated with the presence of cerebral white matter lesions. The observed longitudinal characteristics of the correlation are helpful in assessing whether arteriosclerosis predicts white matter lesions.[25] Serum uric acid (UA) and CF-PWV Studies of carotid radial PWV (CR-PWV), CAVI, ankle brachial index (ABI), and cIMT, and gender differences in the real world population from China have found that all vascular parameters in men are higher than those in women. The relationship between UA and vascular markers has no gender difference except for ABI. UA and CAVI are independently linearly correlated. In populations with higher UA levels, the risk of elevated CF-PWV is increased. Higher UA may primarily affect vascular function rather than vascular structure.[33] A prospective observational and follow-up study involving men and women aged 45 to 75 years was designed as an observational study. Through a questionnaire survey and a 3-year follow-up, vascular function and structural parameters were evaluated without any intervention, and arterial functional indicators such as PWV, CAVI, FMD, ABI, and cIMT were collected, And 2858 plasma biomarkers were included in this study at baseline. This study will provide important information on traditional and new risk factors related to metabolism, and establish a new early detection and scoring system for vascular disease based on comprehensive vascular disease risk factors and vascular function and structure assessment indicators.[47] A study evaluating the relationship between serum bilirubin levels and ABI to determine whether gender affects the correlation between bilirubin levels and peripheral arterial disease (PAD) in hypertensive patients found that serum total bilirubin (TBiL) and direct bilirubin (DBiL) levels in men were higher than those in women. The total bilirubin and DBiL were significantly decreased in the PAD group. After adjusting for cardiovascular risk factors, PAD was independently negatively correlated with TBiL and DBiL, and the relationship between PAD and bilirubin levels was only found in men.[48] A study evaluating the relationship between systemic atherosclerosis and multiple atherosclerotic plaques found that MAP was highly prevalent in this cohort, with a higher prevalence in men than in women. High systemic arteriosclerosis is independently associated with multi-site atherosclerotic plaques (MAP), indicating that arteriosclerosis has complementary value for early recognition and intervention of MAP.[13] A study assessing the arterial function of different vascular related diseases and the potential interrelationship between these diseases and atherosclerosis found compared with participants without vascular-related diseases, those presenting the diseases showed a significantly higher prevalence and age- and sex-adjusted OR of arteriosclerosis. The associations between arteriosclerosis and diseases other than hypertension were largely explained by the association with hypertension, indicating that hypertension could be the single most important factor that leads to arteriosclerosis.[17] A study evaluating the independent relationship between HbA1c and low ABI found that HbA1c is an independent factor associated with lower ABI, linearly correlated with ABI levels, and not related to fasting blood glucose and other cardiovascular factors.[28] A cohort study explored the predictive value of BVHS for new cardiovascular and cerebrovascular events, mainly for CHD and cerebral infarction events. CF-PWV, carotid radial artery PWV, CAVI and ABI are also predictors of CHD and cerebral infarction, among which CAVI is a more stable indicator. In addition, with effective vascular health management and intervention, even high CF-PWV levels at baseline are not necessarily risk factors for cardiovascular and cerebrovascular events. This study preliminarily verified that BVHS has predictive value for CHD in Chinese population, while the predictive value of cerebral infarction needs to be studied.[49] In order to further facilitate clinical practice, BVHS is hereby supplemented and revised.[50] To further advance clinical practice, BVHS is hereby supplemented and revised. The BVHS study (ChiCTR2000034085) was initiated in 2020 and is ongoing, combining vascular structural and functional indicators to further validate the predictive value of BVHS for future cardiovascular events.[51]

Vascular Health Management Throughout the Life Cycle of Tertiary Hospital-Community-Family

The core of the management of VH is to screen out subclinical vascular lesions with early non-invasive examination, improve vascular function by controlling risk factors, prevent the occurrence of CVD, and ultimately reduce the cardiovascular events that cause death and disability. Hierarchical management of different vascular risk groups can also save medical resources and reduce the increasing burden of CVD. Relying on the practical experience of the

"Shougang Model" of hypertension prevention and treatment by the World Health Organization, the "Shougang Vascular Health Management Model" was explored, that is, the integrated mechanism of tertiary hospitals and community medical services, which can implement the whole process management of CVD.[52] Through the information system of the close-knit medical alliance and the embedded "intelligent diagnosis and treatment of cardiovascular and cerebrovascular diseases based on AI" system, the whole process management of VH is realized. Providing clinicians with the intelligent collaborative auxiliary diagnosis and treatment function of CVD and applying it to community health service centers can greatly improve the clinical diagnosis and treatment skills of general practitioners.

By establishing a three-level intelligent diagnosis and treatment service collaboration platform for cardiovascular and cerebrovascular diseases to improve the overall diagnosis and treatment level and provide a complete medical service system, Peking University Shougang Hospital and its four community health service centers were selected to carry out the construction and application of the three-level diagnosis and treatment service collaboration platform for cardiovascular and cerebrovascular diseases, mainly including the establishment of diagnosis and treatment data, intelligent diagnosis and treatment platform and intelligent medical knowledge dissemination network. The system terminal remotely uploads electrocardiogram, echocardiography, cardiovascular CTA, MRI, carotid ultrasound, electroencephalogram, monitor, digital subtraction angiography X-ray imaging system (DSA) and other diagnosis and treatment data to the medical equipment network sharing platform, community hospital staff can independently and professionally operate the above diagnosis and treatment equipment, promote the medical diagnosis and treatment data of medical institutions at all levels to meet the examination quality and technical homogeneity, and apply the tertiary diagnosis and treatment platform for intelligent auxiliary diagnosis. The utilization rate of medical equipment and data resources, patients' awareness of cardiovascular and cerebrovascular diseases, and the satisfaction of medical staff and patients with intelligent diagnosis and treatment services were observed. After the application of the tertiary diagnosis and treatment platform, the diagnosis and treatment service level of each community center was significantly improved, the utilization rate of medical equipment and data resources increased significantly, the patient's awareness of cardiovascular and cerebrovascular diseases was significantly improved, and patients and community medical staff were very satisfied with the application of the tertiary diagnosis and treatment platform.[53] By taking the lifelong management of VH in tertiary hospitals as the leader, and giving full play to the advantages of integration with general medicine in community hospitals, not only CVD patients are managed, but also high-risk groups are detected early, and the early prevention of vascular diseases integrated with traditional Chinese and Western medicine is realized. Adhering to the concept of traditional Chinese medicine prevention before disease, hospitals at all levels have established pre-treatment departments, continuously explored service models and clinical paths for pre-treatment, and established VH management clinical pathways and service models.

Through the extension of the network architecture of community health service organizations, including general practitioners and health service personnel, remote real-time communication of data can be realized with the help of remote monitoring instruments, and then the goal of integrated collaborative service management with hospital health record data as the main line is realized. The construction of the remote monitoring application system allows residents to monitor their own health at home, and through the collaborative analysis of data inside and outside the hospital, they can more accurately grasp the control of health indicators, which is convenient for them to implement refined health management.

Establish a specialist-family physician team in tertiary hospitals, integrate with the family physician team of community health service centers, and provide "group-type" contract services for patients, and the VH services provided by the specialist-family physician team in tertiary hospitals are mainly based on cardiac and vascular medicine specialties. The family physician team of the community health service center mainly provides vascular disease chronic disease management, community rehabilitation and extended family health services for contracted patients.

We carry out health education and publicity in a variety of ways, including patients attending medical institutions, patients serving family doctors, and healthy people in society. Every month, he will give lectures on vascular health at the community health service center and community activity station under Shougang Hospital; In the health programs of TV stations, popularize vascular health knowledge to the people of the whole country; Regularly carry out science popularization on the hospital's official public account platform. Foreign studies have found that behavioral guidance

based on family blood pressure has anti-albuminuria effect on people with microalbuminuria.[54] Face-to-face interviews on chronic disease management were conducted at least quarterly, and 2867 patients with chronic diseases were managed in the Gucheng Community Health Service Center under Beijing Shougang Hospital, and 2149 were archived after the first diagnosis, with a filing rate of 74.95%, and 72.13% could adhere to regular follow-up after filing. The prevalence of hypertension was the highest (88.22%), and the medication was more reasonable, and the blood pressure control was more satisfactory (53.61%), which was similar to foreign studies.[55] It is inseparable from increasing the publicity of the harm of hypertension, improving drug compliance and regular follow-up. The prevalence of CHD was 28.38%. The prevalence of hyperlipidemia was 26.64%, and the medication was more standardized and reasonable, and the blood lipid control was satisfactory (78.99%). The prevalence of diabetes (39.19%) was second only to hypertension, and most diabetic patients were found to have poor blood glucose control (70.94%), stroke prevalence of 14.09%, and prevalence of 2 or more chronic diseases 66.8% during follow-up. The achievements and problems revealed in the above survey provide data support for the direction of our further efforts.[56] Family physicians play an important role in the clinical assessment and monitoring of hemodialysis vascular access.[57]

For health education, Internet of Things diagnosis and treatment, offline or online consultation and other services for patients with vascular diseases, specialists and general practitioners can jointly complete. Specialists can carry out specialized heart and VH management teaching clinics in community health service centers, and general practitioners can also regularly participate in teaching rounds in cardiac and vascular medicine specialty wards of tertiary hospitals, so that more contracted patients can truly feel the authenticity of performance services, and continuously improve the diagnosis and treatment level of general practitioners in community health service centers, so as to provide better medical security and life-cycle health management for patients with vascular diseases.

Intelligent Digital Heart and Vascular Health Model

The dynamic changes of vascular remodeling are the basic mechanism for blood vessels to maintain health and develop diseases.[58] It is of great practical significance to prevent vascular damage with vascular health management as the starting point. Hierarchical management of different vascular risk groups can also save medical resources. Actively explore the embedded "AI -based intelligent diagnosis and treatment of cardiovascular and cerebrovascular diseases" system, which can provide clinicians with intelligent collaborative diagnosis and treatment functions for cardiovascular and cerebrovascular diseases. The predictive value of the BVHS system for CHD has been preliminarily validated.[49] Deep learning models for analyzing electrocardiogram show better performance compared to existing methods such as hardware or rule-based algorithms used to detect or predict CVD.[59] The deep learning model is integrated into the AI-based AtheroEdge-aiP3 framework to determine the risk of CVD/stroke in rheumatoid arthritis patients.[60] AI may improve large vessel occlusions stroke detection and rapid triage necessary for expedited treatment.[61] Compared to existing analysis methods that use humans to visualize or extract manual features of biological signals, deep learning algorithms show very high performance. AI models for diverse cardiovascular-related diseases are being developed, and that they are gradually developing into a form that is suitable for wearable and mobile devices.[62] With the help of artificial intelligence such as wearable devices, not only can the concept of smart family doctors be embodied, but also medical services can be truly extended to patients' homes through information means, which will become a new model of medical and nursing combined home care and full-life vascular health management in the future.

Prospect

With the aging of the population, vascular lesions associated with aging have become a serious social problem, and the early comprehensive maintenance of vascular health provides new ideas and new means for the early prevention and treatment of chronic diseases. The combined application of vascular evaluation indicators and the exploration of novel vascular detection biomarkers have great research prospects, avoiding the limitations of single indicators. The tertiary hospital-community-family diagnosis and treatment model plays a very important role in the whole life cycle management of vascular health. Digitalization, smart healthcare, and deep learning processes have greatly improved the prospects for vascular disease prevention. In the future, convenient, real-time and intelligent AI, Internet and 5G new

technologies will have broad prospects in the prediction, prevention, treatment, rehabilitation and drug research and development of vascular diseases.

Author Contributions

All authors made a significant contribution to the work reported, whether that is in the conception, study design, execution, acquisition of data, analysis and interpretation, or in all these areas; took part in drafting, revising or critically reviewing the article; gave final approval of the version to be published; have agreed on the journal to which the article has been submitted; and agree to be accountable for all aspects of the work.

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Disclosure

The authors report no conflicts of interest in this work.

References

1. Zhao X, Wang H. Proceedings of the 14th China International Congress of Vascular Medicine. *Advances in Cardiology*. 2018;39(02):300–302. doi:10.16806/j.cnki.issn.1004-3934.2018.02.044
2. Zhang Y, Huang W, Wang H. Proceedings of the 17th China International Congress of Vascular Medicine. *Advances in Cardiology*. 2020;41(11):1226–1227. doi:10.16806/j.cnki.issn.1004-3934.2020.11.028
3. Wang H, Tian A, Chen X, et al. Practice Guidelines for Digital Management of the Whole Life Cycle of Intelligent Vascular Health in China (2022 First Report). *Adv Cardiol*. 2023;44(01):71–81. doi:10.16806/j.cnki.issn.1004-3934.2023.01.017
4. China Medicine Education Association Vascular Medicine Professional Committee. Expert consensus on management strategy of non-traditional vascular health risk factors in China(2022 the first report). *Natl Med J China*. 2023;103(4):242–258. doi:10.3760/cma.j.cn112137-20221030-02261
5. Liu H, Liu R, Wang H. Evaluation of vascular endothelial function and its clinical value. *Adv Cardiol*. 2016;37(04):426–430. doi:10.16806/j.cnki.issn.1004-3934.2016.04.026
6. Migliacci R, Guglielmini G, Busti C, Falcinelli E, Minuz P, Gresele P. Walking-induced endothelial dysfunction predicts ischemic cardiovascular events in patients with intermittent claudication. *Vasc Med*. 2021;26(4):394–400. doi:10.1177/1358863X211001927
7. Thijssen DHJ, Bruno RM, van Mil ACCM, et al. Expert consensus and evidence-based recommendations for the assessment of flow-mediated dilation in humans. *Eur Heart J*. 2019;40(30):2534–2547. doi:10.1093/eurheartj/ehz350
8. Wang RJ, Xu C, Tang HF. Reactive hyperemia index as an integrated marker in prediction of bleeding and cardiovascular death in ACS. *Int J Cardiol*. 2023;382:85–86. doi:10.1016/j.ijcard.2023.03.045
9. Liu H, Xie G, Huang W, et al. Rationale and design of a multicenter, randomized, patients-blinded two-stage clinical trial on effects of endothelial function test in patients with non-obstructive coronary artery disease (ENDOFIND). *Int. J Cardiol*. 2021;325:16–22. doi:10.1016/j.ijcard.2020.10.033
10. Kim HL, Lim WH, Seo JB, Chung WY. Prognostic value of reactive hyperemia index using peripheral artery tonometry in patients with heart failure. *Sci Rep*. 2023;13(1):125. doi:10.1038/s41598-023-27454-1
11. Okawa K, Sogo M, Morimoto T, et al. Relationship Between Endothelial Dysfunction and the Outcomes After Atrial Fibrillation Ablation. *J Am Heart Assoc*. 2023;12(11):e 028482. doi:10.1161/JAHA.122.028482

12. Yang X, Xing Y, Xia K, Zhao W. Relationships between peripheral reactive hyperemia index with coronary plaque burden and prognosis in patients with unstable angina pectoris complicated with type 2 diabetes mellitus. *Ann Transl Med*. 2021;9(8):655. doi:10.21037/atm-21-657
13. Liu H, Liu J, Huang W, et al. Association between multi-site atherosclerotic plaques and systemic arteriosclerosis: results from the BEST study (Beijing Vascular Disease Patients Evaluation Study). *Cardiovascular Ultrasound*. 2020;18(1):30. doi:10.1186/s12947-020-00212-3
14. Seekircher L, Tschiderer L, Lind L, et al. Intima-media thickness at the near or far wall of the common carotid artery in cardiovascular risk assessment. *Eur Heart J Open*. 2023;3(5):oead089. doi:10.1093/ehjopen/oead089
15. Willeit P, Tschiderer L, Allara E, et al. Carotid Intima-Media Thickness Progression as Surrogate Marker for Cardiovascular Risk: meta-Analysis of 119 Clinical Trials Involving 100 667 Patients. *Circulation*. 2020;142(7):621–642. doi:10.1161/CIRCULATIONAHA.120.046361
16. Tobe A, Tanaka A, Furusawa K, et al. Heterogeneous Carotid Plaque Predicts Cardiovascular Events after Percutaneous Coronary Intervention. *J Atheroscler Thromb*. 2023;30(9):1187–1197. doi:10.5551/jat.63622
17. Liu H, Xie W, Liu J, et al. Comparison of vascular-related diseases in their associations with carotid femoral pulse wave velocity: from the Beijing Vascular Disease Patients Evaluation Study (BEST Study). *Int. J Clin Pract*. 2019;73(11):e13400. doi:10.1111/ijcp.13400
18. Nagai K, Shibata S, Akishita M, et al. Efficacy of combined use of three non-invasive atherosclerosis tests to predict vascular events in the elderly; carotid intima-media thickness, flow-mediated dilation of brachial artery and pulse wave velocity. *Atherosclerosis*. 2013;231(2):365–370. doi:10.1016/j.atherosclerosis.2013.09.028
19. Liu J, Wang K, Liu H, et al. Cross-Sectional Relationship between Carotid-Femoral Pulse Wave Velocity and Biomarkers in Vascular-Related Diseases. *Int. J Hypertens*. 2020;2020:6578731. doi:10.1155/2020/6578731
20. Kim ED, Ballew SH, Tanaka H, Heiss G, Coresh J, Matsushita K. Short-Term Prognostic Impact of Arterial Stiffness in Older Adults Without Prevalent Cardiovascular Disease. *Hypertension*. 2019;74(6):1373–1382. doi:10.1161/HYPERTENSIONAHA.119.13496
21. Niiranen TJ, Kalesan B, Mitchell GF, Vasan RS. Relative Contributions of Pulse Pressure and Arterial Stiffness to Cardiovascular Disease. *Hypertension*. 2019;73(3):712–717. doi:10.1161/HYPERTENSIONAHA.118.12289
22. Zhao X, Bo L, Zhao H, et al. Cardio-ankle vascular index value in dyslipidemia patients affected by cardiovascular risk factors. *Clin. Exp Hypertens*. 2018;40(4):312–317. doi:10.1080/10641963.2017.1377213
23. Wang H. Cardio-ankle vascular index: a new marker for vascular health evaluation (experience from China). *J Hum Hypertens*. 2015;29(2):136. doi:10.1038/jhh.2014.68
24. Liu J, Liu H, Zhao H, et al. Descriptive study of relationship between cardio-ankle vascular index and biomarkers in vascular-related diseases. *Clin. Exp Hypertens*. 2017;39(5):468–472. doi:10.1080/10641963.2016.1273946
25. Liu H, Liu J, Zhao H, et al. Association of brain white matter lesions with arterial stiffness assessed by cardio-ankle vascular index. The Beijing Vascular Disease Evaluation STudy (BEST). *Brain Imaging and Behavior*. 2021;15(2):1025–1032. doi:10.1007/s11682-020-00309-3
26. Shirai K, Utino J, Otsuka K, Takata M. A novel blood pressure-independent arterial wall stiffness parameter; cardio-ankle vascular index (CAVI). *J Atheroscler Thromb*. 2006;13(2):101–107. doi:10.5551/jat.13.101
27. Okamoto Y, Miyoshi T, Ichikawa K, Takaya Y, Nakamura K, Ito H. Cardio-Ankle Vascular Index as an Arterial Stiffness Marker Improves the Prediction of Cardiovascular Events in Patients without Cardiovascular Diseases. *J Cardiovasc Dev Dis*. 2022;9(11):368. doi:10.3390/jcdd9110368
28. Liu H, Liu J, Zhao H, et al. Relationship between glycated hemoglobin and low Ankle-Brachial Index: a cross-sectional observational study from the Beijing Vascular Disease Evaluation Study (BEST Study). *Int. Angiol*. 2019;38(6):502–507. doi:10.23736/S0392-9590.19.04210-X
29. Abboud H, Monteiro Tavares L, Labreuche J, et al. Impact of Low Ankle-Brachial Index on the Risk of Recurrent Vascular Events. *Stroke*. 2019;50(4):853–858. doi:10.1161/STROKEAHA.118.022180
30. Lee M, Smolderen KG, Ionescu C, Hillegass WB, Romain G, Mena-Hurtado C. Lower extremity symptoms and ankle-brachial index screening as predictors of cardiovascular outcomes in Black adults. *Vasc Med*. 2023;28(3):197–204. doi:10.1177/1358863X231151729
31. Szaló G, Hellgren MI, Allison M, et al. Impaired artery elasticity predicts cardiovascular morbidity and mortality- A longitudinal study in the Vara-Skövde Cohort. *J Hum Hypertens*. 2023. doi:10.1038/s41371-023-00867-1
32. Liao KM, Chang CW, Wang SH, Chang YT, Chen YC, Wang GC. The first harmonic of radial pulse wave predicts major adverse cardiovascular and microvascular events in patients with type 2 diabetes. *J Diabetes Complications*. 2019;33(11):107420. doi:10.1016/j.jdiacomp.2019.107420
33. Liu H, Liu J, Zhao H, et al. Relationship between Serum Uric Acid and Vascular Function and Structure Markers and Gender Difference in a Real-World Population of China-From Beijing Vascular Disease Patients Evaluation Study (BEST) Study. *J Atheroscler Thromb*. 2018;25(3):254–261. doi:10.5551/jat.39685
34. Liu J, Wang K, Liu H, et al. Relationship between carotid-femoral pulse wave velocity and uric acid in subjects with hypertension and hyperuricemia. *Endocrine Journal*. 2019;66(7):629–636. doi:10.1507/endocrj.EJ18-0570
35. Habib SS, Al-Khlaiwi T, Almushawah A, Alsomali A, Habib SA. Homocysteine as a predictor and prognostic marker of atherosclerotic cardiovascular disease: a systematic review and meta-analysis. *Eur Rev Med Pharmacol Sci*. 2023;27(18):8598–8608. doi:10.26355/eurrev_202309_33784
36. Manolis AA, Manolis TA, Melita H, Mikhailidis DP, Manolis AS. Low serum albumin: a neglected predictor in patients with cardiovascular disease. *Eur J Intern Med*. 2022;102:24–39. doi:10.1016/j.ejim.2022.05.004
37. Jiang H, Li J, Yu K, et al. Associations of estimated glomerular filtration rate and blood urea nitrogen with incident coronary heart disease: the Dongfeng-Tongji Cohort Study. *Sci Rep*. 2017;7(1):9987. doi:10.1038/s41598-017-09591-6
38. Wei Y, Li W, Luan H, et al. The association of glycated hemoglobin A1c with coronary artery disease, myocardial infarction, and severity of coronary lesions. *J. Investig Med*. 2023;71(3):202–211. doi:10.1177/10815589221140593
39. Simmons RK, Sharp S, Boekholdt SM, et al. Evaluation of the Framingham risk score in the European Prospective Investigation of Cancer-Norfolk cohort: does adding glycated hemoglobin improve the prediction of coronary heart disease events? *Arch Intern Med*. 2008;168(11):1209–1216. doi:10.1001/archinte.168.11.1209
40. Abe S, Haruyama Y, Kobashi G, et al. Effect of Novel Stratified Lipid Risk by "LDL-Window" and Flow-Mediated Dilation on the Prognosis of Coronary Artery Disease Using the FMD-J Study A Data. *Circ J*. 2022;86(9):1444–1454. doi:10.1253/circj.CJ-21-1068
41. Wen F, Liu Y, Wang H. Clinical Evaluation Tool for Vascular Health-Endothelial Function and Cardiovascular Disease Management. *Cells*. 2022;11(21). doi:10.3390/cells11213363
42. Qureshi AI, Caplan LR. Intracranial atherosclerosis. *Lancet*. 2014;383(9921):984–998. doi:10.1016/S0140-6736(13)61088-0

43. Yang S, Hoshino M, Koo BK, et al. Relationship of Plaque Features at Coronary CT to Coronary Hemodynamics and Cardiovascular Events. *Radiology*. 2022;305(3):578–587. doi:10.1148/radiol.213271
44. Lessick J, Mutlak D, Mutlak M, et al. Left atrial function by cardiac computed tomography is a predictor of heart failure and cardiovascular death. *Eur Radiol*. 2022;32(1):132–142. doi:10.1007/s00330-021-08093-4
45. Iatan I, Guan M, Humphries KH, Yeoh E, Mancini GBJ. Atherosclerotic Coronary Plaque Regression and Risk of Adverse Cardiovascular Events: a Systematic Review and Updated Meta-Regression Analysis. *JAMA Cardiol*. 2023;8(10):937–945. doi:10.1001/jamacardio.2023.2731
46. Lv R, Wang L, Maehara A, et al. Combining IVUS + OCT Data, Biomechanical Models and Machine Learning Method for Accurate Coronary Plaque Morphology Quantification and Cap Thickness and Stress/Strain Index Predictions. *J Funct Biomater*. 2023;14(1):41. doi:10.3390/jfb14010041
47. Liu H, Liu J, Zhao H, et al. The design and rationale of the Beijing Vascular Disease Patients Evaluation Study (BEST study). *Contemporary Clinical Trials Communications*. 2017;7:18–22. doi:10.1016/j.conctc.2017.05.004
48. Lan Y, Liu H, Liu J, et al. The Relationship Between Serum Bilirubin Levels and Peripheral Arterial Disease and Gender Difference in Patients With Hypertension: BEST Study. *Angiology*. 2020;71(4):340–348. doi:10.1177/0003319719900734
49. Liu H, He Y, Liu J, et al. The predictive value of vascular health indicators on new cardiovascular and cerebrovascular events: a preliminary verification of Beijing vascular health grading standards. *J Peking Univ*. 2020;52(03):514–520. doi:10.19723/j.issn.1671-167X.2020.03.018
50. Jiang S, Wang H. Intelligent full-life cycle cardiac and vascular health management based on Beijing vascular health grading guidance Chinese. *J Clin*. 2019;13(11):868–871. doi:10.3877/cma.j.issn.1674-0785.2019.11.015
51. Liu H, Zhou X, Liu J, et al. Rationale and design of the application value of Beijing Vascular Health Stratification (BVHS): predictive value of combined assessment of vascular structure and function for cardiovascular events in general Chinese population. *BMC Cardiovasc Disord*. 2021;21(1):498. doi:10.1186/s12872-021-02289-8
52. Wang H, Chen X. Relying on the information-based full-life cycle vascular health management and cardiovascular disease community prevention and treatment strategies. *Chine J Phys*. 2020;22(9):1281–1284. doi:10.3760/cma.j.cn431274-20200721-01011
53. Nie N, Zhao X, Wang Y, et al. Construction and application research of collaborative application platform for tertiary diagnosis and treatment services for cardiovascular and cerebrovascular diseases. *China's Health Industry*. 2018;15(32):47–48. doi:10.16659/j.cnki.1672-5654.2018.32.047
54. Munakata M, Hattori T, Kubota-Nakayama F, et al. Home Blood Pressure-based Guidance Did Not Increase Anti-albuminuric Effects on Diagnostic Provision of Microalbuminuria in School Workers: a Miyagi Karoshi Prevention Study. *Intern Med*. 2023;62(8):1123–1130. doi:10.2169/internalmedicine.0107-22
55. Fakhri G, Assaad S, Chaaya M. Hypertension prevalence and control among community-dwelling Lebanese older adults. *J Clin Hypertens*. 2020;22(9):1727–1731. doi:10.1111/jch.13995
56. Yang Z, Zhong S, Xie Y, et al. A brief analysis of the current situation of chronic disease management in Gucheng Community Health Service Center in Beijing. *Chine J Clin*. 2022;16(06):474–480. doi:10.3877/cma.j.issn.1674-0785.2022.06.003
57. Arasu R, Jegatheesan D, Sivakumaran Y. Overview of hemodialysis access and assessment. *Can Fam Physician*. 2022;68(8):577–582. doi:10.46747/cfp.6808577
58. Schwartz MA, Vestweber D, Simons M. A unifying concept in vascular health and disease. *Science*. 2018;360(6386):270–271. doi:10.1126/science.aat3470
59. Krittanawong C, Johnson KW, Rosenson RS, et al. Deep learning for cardiovascular medicine: a practical primer. *Eur Heart J*. 2019;40(25):2058–2073. doi:10.1093/eurheartj/ehz056
60. Al-Maini M, Maindarkar M, Kitas GD, et al. Artificial intelligence-based preventive, personalized and precision medicine for cardiovascular disease/stroke risk assessment in rheumatoid arthritis patients: a narrative review. *Rheumatol Int*. 2023;43(11):1965–1982. doi:10.1007/s00296-023-05415-1
61. Murray NM, Unberath M, Hager GD, Hui FK. Artificial intelligence to diagnose ischemic stroke and identify large vessel occlusions: a systematic review. *J Neurointerv Surg*. 2020;12(2):156–164. doi:10.1136/neurintsurg-2019-015135
62. Lee S, Chu Y, Ryu J, Park YJ, Yang S, Koh SB. Artificial Intelligence for Detection of Cardiovascular-Related Diseases from Wearable Devices: a Systematic Review and Meta-Analysis. *Yonsei Med J*. 2022;63(Suppl):S93–S107. doi:10.3349/ymj.2022.63.S93