Early Warning Mechanisms and Comprehensive Interventions for the Progression of Hypertension to Intracranial Hemorrhage in the Elderly

Haocong Zhai
Weifang Nursing Vocational College, Weifang, Shandong, China

Abstract: With the increasingly severe aging of China's population, the prevalence of hypertension among the elderly has risen annually, making it one of the common chronic diseases in this demographic. Due to physiological characteristics such as reduced vascular elasticity and impaired blood pressure regulation, elderly hypertensive individuals are highly susceptible to intracranial hemorrhage (ICH). This study aims to elucidate the early warning mechanisms through a systematic review of existing research and propose targeted comprehensive intervention strategies. Individual patient differences, such as comorbidities (e.g., diabetes, coronary heart disease), physiological status (e.g., renal function, cognitive ability), and treatment tolerance, are key influencing factors in the progression from hypertension to ICH and the selection of intervention measures. For example, patients with diabetes or proteinuria may need to prioritize the use of kidney protectants (e.g., ACEIs or ARBs), while patients with coronary heart disease may be more suitable for beta-blockers or CCBs. Factors such as differences in drug metabolism, vascular fragility, and self-management ability further require the development of personalized treatment plans and lifestyle adjustment strategies. Comprehensive interventions need to be closely integrated with these individual characteristics to optimize efficacy and safety. Methods: Based on multidimensional clinical and basic research evidence, this study analyzes warning indicators including blood pressure abnormalities, vascular structural and functional changes, and hemorheological abnormalities, and integrates comprehensive measures such as pharmacological interventions, lifestyle adjustments, regular monitoring, and health education. The progression from hypertension to ICH in the elderly involves multiple pathological processes. Early identification of warning signals and implementation of comprehensive interventions can significantly reduce the risk of ICH. Conclusion: Current early warning mechanisms and intervention measures have limitations (e.g., suboptimal specificity of some indicators and insufficient validation of long-term efficacy). Future research should further explore the underlying mechanisms, optimize intervention protocols, and strengthen multidisciplinary collaboration to achieve precise prevention and control of ICH.

Keywords: Elderly Hypertension; Intracranial Hemorrhage; Early Warning Mechanisms; Comprehensive Interventions

1. Introduction

With the rising prevalence of hypertension among the elderly, intracranial hemorrhage (ICH), as its most severe complication, is characterized by high rates of disability and mortality, imposing a heavy burden on patients' families. Investigating the risk factors contributing to the progression from hypertension to ICH and improving patient prognosis are of critical importance[5]. Elderly hypertensive individuals are prone to ICH due to physiological changes such as vascular aging, reduced elasticity, poor blood pressure control, and autonomic nervous system dysfunction, which lead to significant blood pressure fluctuations and increased risk of cerebral vascular rupture. The specific mechanisms underlying ICH remain unclear. This study synthesizes existing research to systematically clarify the early warning mechanisms and propose comprehensive intervention strategies[6].

2. Abnormal Blood Pressure

Fluctuations in blood pressure are a key

indicator of ICH risk. Chronic hypertension can induce pathological changes in vascular walls, such as hyaline degeneration and intimal thickening, leading to reduced vascular elasticity. During strenuous activity or abnormal emotional fluctuations, the incidence of ICH significantly increases. Studies have shown that a 10 mmHg increase in systolic blood pressure raises the risk of ICH by approximately 20%. Significant blood pressure variability is also a notable warning signal-elderly hypertensive patients often experience substantial blood pressure fluctuations and increased variability due to autonomic nervous system dysfunction and reduced baroreceptor sensitivity, which serve as important warning indicators[7].

Blood pressure variability (BPV) refers to the degree of blood pressure fluctuation over a certain period, including short-term (e.g., intra-day/nighttime) and long-term (e.g., weekly/monthly) variations. Elderly hypertensive patients exhibit markedly elevated BPV due to autonomic dysfunction and impaired baroreceptor sensitivity. Research indicates that increased BPV can damage vascular endothelial function and promote atherosclerosis progression, thereby elevating the risk of ICH. Ambulatory blood pressure monitoring is effective in assessing BPV, with insufficient nocturnal blood pressure decline (non-dipping pattern) and elevated morning blood pressure surge (an increase of ≥20 mmHg in systolic pressure within 2–3 hours after waking compared to the nighttime minimum) serving as key predictors of ICH[8].

3. Vascular Structural and Functional Changes

Abnormalities in cerebral vascular structure and function are another critical factor in the progression from hypertension to ICH in the elderly. With aging and prolonged hypertension, cerebral vessels undergo a series of structural changes, such as thickening of small vessel walls, luminal narrowing, and microaneurysm formation (detectable via cranial magnetic resonance imaging, MRI), as well as lesions like white matter rarefaction and lacunar infarcts. These changes increase vascular fragility, making rupture and bleeding more likely[9].

4. Hemorheological Abnormalities

Impaired erythrocyte deformability hinders their passage through microvessels, leading to microcirculatory disorders. Hyperactive platelet function increases platelet aggregation, promoting thrombus formation; thrombus detachment or vascular rupture may trigger ICH. Detection of hemorheological indicators-such as whole blood viscosity, plasma viscosity, erythrocyte deformation index, and platelet aggregation rate-can help identify abnormalities and provide an early warning for ICH[10].

5. Other Warning Indicators

In addition to the above metrics, serum biomarkers (e.g., homocysteine [Hcy], C-reactive protein [CRP], matrix metalloproteinases [MMPs]) have emerged as research focal points in recent years. Hcy, a sulfur-containing amino acid, can damage vascular endothelial cells, promote atherosclerosis, and facilitate thrombosis when elevated, thereby increasing the risk of ICH [11]. CRP, an inflammatory marker, reflects chronic inflammation induced by hypertension; elevated CRP levels can exacerbate vascular wall inflammation and raise ICH risk through inflammatory pathways [12]. MMPs degrade extracellular matrix components (e.g., collagen, elastin) in vascular walls, compromising structural integrity, and their elevated levels are closely associated with ICH occurrence. Furthermore, cognitive dysfunction and a history of falls in elderly hypertensive patients may also heighten ICH risk: cognitive impairment may lead to poor self-protection, non-adherence to medication, and uncontrolled blood pressure, while falls can directly cause vascular injury and bleeding[13].

6. Comprehensive Intervention Measures for the Progression of Hypertension to ICH in the Elderly

6.1 Pharmacological Interventions

Pharmacological treatment is a core strategy for controlling hypertension and reducing the risk of ICH. Antihypertensive medications should be selected based on individual patient conditions (e.g., comorbidities, tolerability) to achieve effective blood pressure control. Commonly used agents include calcium channel blockers (CCBs), angiotensin-converting enzyme inhibitors (ACEIs), angiotensin II receptor blockers (ARBs), and diuretics. For elderly hypertensive patients, the general target blood pressure is <150/90 mmHg; if tolerated, it can be

further reduced to <140/90 mmHg[14].

When selecting antihypertensive drugs, comorbidities must be considered. For example, ACEIs or ARBs are preferred for patients with diabetes or proteinuria, while beta-blockers or CCBs are suitable for those with coronary artery disease. It is essential to avoid excessive blood pressure reduction, which may lead to inadequate cerebral perfusion. Additionally, for patients with hyperhomocysteinemia, supplementation with folic acid, vitamin B6, and vitamin B12 can lower Hcy levels and reduce the risk of ICH[15]. Patients with a hypercoagulable state may use antiplatelet or anticoagulant agents under medical guidance, with close monitoring for bleeding risks.

7. Lifestyle Adjustments

Lifestyle modifications are a crucial component of comprehensive interventions, playing a key role in controlling blood pressure, improving vascular function, and reducing the risk of ICH [1].

7.1 Dietary Interventions

Elderly hypertensive patients should adhere to a diet characterized by low salt (daily sodium intake <5 g), low fat (reduced intake of animal fats and fried foods), and high fiber (increased consumption of vegetables, fruits, whole grains, and legumes) to maintain blood pressure stability [2].

7.2 Exercise and Psychological Regulation

Appropriate exercise (e.g., walking, jogging, tai chi, swimming) enhances cardiopulmonary function, improves vascular elasticity, and lowers blood pressure. Elderly hypertensive patients should engage in moderate-intensity aerobic activities (3–5 times/week, 30–60 minutes/session) based on their individual conditions, avoiding strenuous exercise. Additionally, maintaining a positive mindset, minimizing emotional fluctuations, and reducing stress-induced blood pressure elevation are important. Ensuring adequate sleep and adhering to regular sleep-wake cycles are also recommended [3].

7.3 Smoking Cessation and Alcohol Limitation

Both smoking and excessive alcohol consumption can damage blood vessels and exacerbate blood pressure volatility. Alcohol intake should be limited to <25 g/day for men (approximately 750 mL beer) and <15 g/day for women (approximately 200 mL wine), and smoking cessation is strongly advised [4].

8. Regular Monitoring and Follow-Up

Regular monitoring and follow-up are essential for detecting abnormalities in warning indicators and adjusting interventions.

8.1 Blood Pressure Monitoring

Elderly hypertensive patients should undergo regular home blood pressure monitoring (morning and evening, 1 reading each time, recorded daily) and clinic blood pressure measurements (every 1–3 months, with treatment adjustments based on results). Home monitoring more accurately reflects daily blood pressure levels.

8.2 Ancillary Examinations

Periodic assessments of complete blood count, biochemical indicators (liver and kidney function, lipids, glucose, Hcy, etc.), coagulation function, electrocardiogram, cranial CT or MRI, and vascular ultrasound can help identify hemorheological abnormalities, vascular structural and functional changes, and evaluate intervention efficacy. A structured follow-up system should be established, wherein physicians adjust treatment plans and lifestyle recommendations based on the patient's condition and test results to improve adherence.

9. Health Education and Psychological Interventions

9.1 Health Education

Through community lectures, informational materials, and other means, patients should be educated about hypertension and ICH, including risk factors, warning signs, and preventive measures. Guidance on proper blood pressure measurement, rational medication use, and adherence to a healthy lifestyle can enhance patients' self-management capabilities.

9.2 Psychological Interventions

Elderly hypertensive patients often experience anxiety and depression due to concerns about disease prognosis and declining quality of life. These negative emotions can elevate blood pressure and worsen the condition. Psychological counseling (e.g., individual

therapy, family support, and social care) should be strengthened to help patients establish a positive attitude toward their illness, alleviate adverse emotions, and improve treatment adherence and mental health.

10. Conclusion and Outlook

The progression from hypertension to ICH in the elderly is a complex process involving multiple factors, including blood pressure abnormalities, vascular structural and functional changes, and hemorheological abnormalities. Monitoring these warning indicators enables early prediction of ICH, and implementing comprehensive interventions-combining pharmacological treatment, lifestyle adjustments, regular monitoring, and health education-can effectively reduce the risk of ICH and improve patient outcomes.

Current research has limitations, such as the need for improved specificity of certain warning indicators and further validation of the long-term efficacy of interventions. Future studies should focus on: The progression of hypertension to intracranial hemorrhage (ICH) in the elderly is a complex process involving multiple factors, including abnormal blood pressure, structural and functional changes in blood vessels, and abnormalities in hemorheology. Monitoring these warning indicators can help predict intracranial hemorrhage early, and implementing comprehensive intervention measures-combining pharmacological treatment, lifestyle adjustments, regular monitoring, and health education-can effectively reduce the risk of ICH and improve patient outcomes. Current research has certain limitations. For example, the specificity of some warning indicators needs to be improved, and the long-term efficacy of intervention measures also requires further verification. Future research should further explore the underlying mechanisms, optimize intervention protocols, and strengthen multidisciplinary collaboration. Specifically, more specific clinical validation is needed in terms of precise drug intervention: Design a one - year, single - city (e.g., Rizhao) representative of the Shandong region, multi - center, large - sample, randomized, double - blind, placebo - controlled clinical trial involving 5,000 elderly hypertensive patients (aged ≥65 years, blood pressure 140 - 179/90 - 109 mmHg, excluding those with severe liver or kidney dysfunction, malignant tumors, and a history of previous intracranial hemorrhage). Based on home - measured blood pressure results, patients are subdivided into a isolated systolic hypertension group (systolic blood pressure ≥140 mmHg and diastolic blood pressure <90 mmHg), a mixed - type hypertension group (systolic blood pressure ≥140 mmHg and diastolic blood pressure ≥90 mmHg), and a blood pressure variability - increased group (nocturnal blood pressure decline <10% or morning blood pressure surge ≥20 mmHg). For each subgroup, three intervention schemes are set: Group A adopts a conventional dose of calcium channel blockers (CCBs, such as amlodipine 5 mg/d) combined with angiotensin - converting enzyme inhibitors (ACEIs, such as benazepril 10 mg/d); Group B, on the basis of Group A, individually adjusts the drug dose according to the results of the renin - angiotensin - aldosterone system (RAAS) activity test (adding ARB drugs for those with plasma renin activity >1.0 $ng \cdot ml^{-1} \cdot h^{-1}$), and Group C is the control group, given a placebo combined with basic lifestyle interventions (low - salt diet and regular exercise). The primary observation indicators are the incidence of ICH within one year (diagnosed by head CT/MRI screening once a year), the disability rate (modified Rankin Scale score ≥3), and the all - cause mortality rate. The secondary indicators include the blood pressure control compliance rate (systolic blood pressure <140 mmHg and diastolic blood pressure <90 mmHg, or adjusted target values according to age/comorbidities), blood pressure variability indicators (24 - hour systolic blood pressure standard deviation, morning blood pressure surge), vascular endothelial function (brachial artery flow - mediated dilation FMD ≥7%), hemorheological parameters (whole - blood high - shear viscosity <5.0 mPa·s, plasma viscosity <1.6 mPa·s), and the incidence of drug adverse reactions (such as hypotension, cough, and hyperkalemia). During the study, follow - up is conducted once every three months. Blood pressure and heart rate measurement: Use a calibrated Yuwell brand electronic blood pressure monitor. After the patient sits quietly for 10 minutes, measure the blood pressure in the right upper arm (take the average of the last two of three consecutive measurements), and simultaneously record the systolic blood pressure, diastolic blood pressure, and heart rate to evaluate whether the blood pressure is up to the standard (a clinic blood pressure <140/90 mmHg is considered up to the

standard). Medication record: Inquire and record the patient's medication compliance (regular/occasional missed doses/stopped taking), changes in the types/doses of antihypertensive drugs, and whether any drug - related discomfort symptoms (such as dizziness and dry cough) occur. ③ Basic conditions and living habits: Measure height and weight and calculate the BMI, and record weight changes. Inquire whether the patient has experienced hypertension - related symptoms such as dizziness and chest tightness in the past three months, and record living habits such as diet (low - salt/ordinary), exercise (number of weekly exercise sessions), and sleep duration. Cognitive function assessment (mini - mental state examination MMSE ≥24) and fall risk assessment (using the Morse Fall Scale) are carried out once a month. Through intention - to - treat analysis (ITT) and per - protocol set analysis (PP), the efficacy differences among the three groups are compared to clarify the precise prevention and control effects of different drug combinations and individualized schemes on the ICH risk of specific hypertensive subgroups, providing high - level evidence - based medical evidence for optimizing the antihypertensive treatment strategies of elderly hypertensive patients. These efforts aim to achieve precise prevention and control of intracranial hemorrhage.

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