INPLASY

Carotid Atherosclerosis Burden in Hypertensive Patients at High Altitudes: A Systematic Review and Meta-Analysis

INPLASY202650092
doi: 10.37766/inplasy2026.5.0092
Received: 16 May 2026
Published: 16 May 2026

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ADMINISTRATIVE INFORMATION

Support - Shigatse City Natural Science Foundation.

Review Stage at time of this submission - Completed but not published.

Conflicts of interest - None declared.

INPLASY registration number: INPLASY202650092

Amendments - This protocol was registered with the International Platform of Registered Systematic Review and Meta-Analysis Protocols (INPLASY) on 16 May 2026 and was last updated on 16 May 2026.

INTRODUCTION

Review question / Objective This systematic review aims to evaluate the incidence of carotid atherosclerosis and its influencing factors in hypertensive patients living at high-altitude areas. We mainly compare the incidence of carotid atherosclerotic plaques and carotid intima-media thickness (CIMT) between hypertensive patients in plateau and plain regions. Subgroup analyses will be conducted to explore the effects of altitude gradient, age, and study type on carotid atherosclerosis risk in hypertensive populations. We also assess publication bias to verify the reliability of pooled results, so as to provide evidence-based basis for early prevention of cerebrovascular diseases in high-altitude hypertensive patients.

Rationale Hypertension is a major risk factor for carotid atherosclerosis and subsequent cerebrovascular events. High-altitude environments are characterized by hypoxia, low pressure and special metabolic changes, which may aggravate vascular injury in hypertensive patients. Current primary studies have reported inconsistent incidence rates of carotid atherosclerosis among plateau-living hypertensive patients, lacking quantitative pooled evidence. The correlation between altitude level, age and carotid atherosclerosis in this population remains unclear. Therefore, it is necessary to perform a meta-analysis to synthesize existing observational data, quantify the overall incidence of carotid atherosclerosis, and identify key associated factors. This will help guide targeted screening and early intervention for high-altitude hypertensive groups.

Condition being studied This study focuses on two core health conditions: hypertension and carotid atherosclerosis. Hypertension is defined as persistently elevated blood pressure. Carotid atherosclerosis mainly manifests as carotid atherosclerotic plaques and increased carotid intima-media thickness (CIMT), which are early markers of systemic atherosclerosis and important predictors of ischemic stroke. High-altitude

hypoxic environment interacts with hypertension to accelerate carotid vascular remodeling and atherosclerotic progression. This review investigates the prevalence and risk factors of carotid atherosclerosis specifically in hypertensive populations residing at high-altitude regions (≥2000 m above sea-level).

METHODS

Search strategy Electronic databases include CNKI, Wanfang Database, VIP Database, Chinese Biomedical Literature Database (CBM), PubMed, and Web of Science. Studies published from January 2007 to May 2025 are retrieved. Search terms: (hypertension OR hypertensive patients) AND (high-altitude OR plateau) AND (carotid atherosclerosis OR carotid plaque OR carotid intima-media thickness OR CIMT). Reference lists of included articles are manually screened to supplement potential eligible studies. No language restriction is applied.

Participant or population Hypertensive patients diagnosed with hypertension, including those living in high-altitude areas (≥2000 m above sea-level) and plain areas. Participants are divided by age (> 60 years / ≤60 years) and altitude gradient (2000–2500 m / >2500 m). No restrictions on gender or race.

Intervention Exposure factor: long-term residence at high-altitude areas (≥2000 m) with hypertension status. Comparator: hypertensive patients living in plain areas; younger hypertensive patients (≤60 years old).

Comparator Hypertensive patients living in plain-land areas; younger hypertensive patients (aged ≤60 years).

Study designs to be included Cross-sectional studies and case-control studies investigating carotid atherosclerosis in hypertensive patients.

Eligibility criteria Inclusion: studies reporting carotid atherosclerosis data in hypertensive patients; clear altitude classification; available original data.
Exclusion: reviews, animal studies, conference abstracts, duplicate publications, incomplete-data studies.

Information sources Six electronic databases: CNKI, Wanfang, VIP, CBM, PubMed, Web of Science. Reference lists of included papers are manually screened.

Main outcome(s) Incidence of carotid atherosclerotic plaques in hypertensive patients.

Additional outcome(s) Carotid intima-media thickness (CIMT); subgroup differences by altitude, age and study type.

Data management Two independent reviewers extract data. Disagreements are resolved by discussion or a third senior reviewer.

Quality assessment / Risk of bias analysis The Newcastle-Ottawa Scale (NOS) is used to evaluate the methodological quality of cross-sectional and case-control studies.

Strategy of data synthesis Meta-analysis uses Review Manager 5.4. RR for incidence data, MD for continuous CIMT data. Fixed-effect for $I^2 < 50\%$, random-effect for $I^2 \geq 50\%$.

Subgroup analysis Subgroup analyses by altitude (2000-2500 m vs >2500 m), age (>60 years vs ≤60 years), and study type (cross-sectional vs case-control).

Sensitivity analysis One-by-one exclusion of individual studies to verify the stability of pooled meta-analysis results.

Country(ies) involved China.

Keywords High altitude; Hypertension; Carotid atherosclerosis; Carotid intima-media thickness; Meta-analysis.

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