JCS Journal of Caring Sciences

eISSN: 2251-9920 https://jcs.tbzmed.ac.ir

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DOI: 10.34172/jcs.33784

Please cite this article as: Rajabpour M, Heydari A, Manzari Z, Ghandehari K, Mirhaghi A. Modifiable Risk Factors Associated with Readmission in Stroke Survivors: An Umbrella Review. J Caring Sci 2026; 15(3): x-x. doi: 10.34172/jcs.33784

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Modifiable Risk Factors Associated with Readmission in Stroke Survivors: An Umbrella Review

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Review Article
Received: October 06, 2024
Revised: January 04, 2025
Accepted: October 05, 2025
E Published: August 29, 2026

Mohammad Rajabpour[1], Abbas Heydari[2], Zahrasadat Manzari[2], Kavian Ghandehari[3], Amir Mirhaghi[4,5*]. Modifiable Risk Factors Associated with Readmission in Stroke Survivors: An Umbrella Review. JCS

Abstract

Introduction: It has not yet been established whether the risk factors for readmissions of stroke survivors differ from those that contribute to the occurrence of this medical condition. This umbrella review aimed to (1) identify modifiable risk factors for 30-day and 1-year readmission after stroke and (2) develop an evidence-informed illustrative model describing their relationships with readmission.

Methods: This umbrella review was conducted according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2020 guidelines. A systematic search of PubMed, Web of Science, Cochrane Library, CINAHL, and Scopus was conducted for studies published up to June 2024. Two reviewers independently screened titles, abstracts, and full texts

for eligibility and extracted the relevant data using a standardized data extraction form. Any disagreements were resolved through discussion until consensus was reached.

Results: Thirty-one systematic reviews and meta-analyses were included. Hypertension (30-day OR=1.10–2.14; 1-year OR=1.18–2.60), atrial fibrillation (30-day OR=1.26–2.13; 1-year OR=0.57–2.40), diabetes mellitus (30-day OR=1.15–1.40; 1-year OR=0.91–1.40), and treatment non-adherence were the main modifiable risk factors associated with post-stroke readmission. An evidence-informed illustrative model was developed to illustrate the interrelationships among these factors and their contribution to readmission risk.

Conclusion: Addressing modifiable cardiovascular risk factors and improving treatment adherence are essential to reducing hospital readmissions after stroke. The developed evidence-informed illustrative model highlights the interrelationships among hypertension, atrial fibrillation, diabetes mellitus, treatment adherence, and post-discharge support, providing a framework for targeted interventions to reduce readmission.

Keywords: Stroke, Readmission, Risk Factors, Umbrella Review

Introduction

Stroke is a significant public health issue worldwide due to its high prevalence, mortality rate, disability rate, and incidence of complications.[1,2] The frequency of readmission has been emphasized in various studies because of its association with increased mortality, especially within 30, 60, 90 days, and even 1 year after discharge.[1] Reports indicate that the frequency of readmissions during the first year ranges from 31% to 56.1%, [2] with 17.4% of cases occurring within the first 30 days,[3] and half within the first three months.[4] Stroke readmission can be a concern for both patients and healthcare providers. The cycle of discharge followed by unplanned readmission poses significant challenges, disrupting a patient's recovery and placing considerable strain on the healthcare system. Distinguishing between risk factors for initial stroke and those specifically associated with readmission is crucial for several reasons. First, the underlying mechanisms and clinical implications of these risk factors can differ markedly; for instance, while factors like hypertension and diabetes may contribute to the initial stroke event, their role in post-discharge readmission may be influenced by the patient's adherence to treatment, comorbidities, and access to follow-up care. Second, targeted interventions can be developed by understanding these distinctions, allowing healthcare providers to implement tailored strategies that address the specific needs of stroke survivors during their recovery phase. This differentiation not only enhances the quality of care but also aids in the allocation of resources, ultimately reducing the incidence of preventable readmissions and improving overall patient outcomes. Therefore, identifying and mitigating preventable risk factors for readmission is essential for optimizing stroke care and ensuring a smoother transition from hospital to home.[2, 5]

Risk factors such as atrial fibrillation (AF), hypertension (HTN), diabetes mellitus (DM), and infections are documented as the most prevalent factors contributing to stroke.[2] Although these risk factors have been well described in previous research,[3, 6, 7] there is limited information on their association with readmission in stroke survivors.[5, 8] Various studies have reported different odds ratios for these risk factors in relation to post-stroke readmission, with a focus also on non-modifiable factors like age, gender, and race.[2, 9, 10]

Several systematic reviews have examined individual predictors of hospital readmission after stroke; however, their findings are often limited to specific risk factors, patient populations, follow-up periods, or clinical settings. Consequently, the available evidence remains fragmented, making it difficult for clinicians and policymakers to identify the most important modifiable risk factors that can be targeted to reduce readmissions.[11-15] To date, no umbrella review has comprehensively synthesized the evidence from existing systematic reviews and meta-analyses or integrated these findings into an evidence-informed illustrative model to clarify the relationships among modifiable risk factors associated with post-stroke readmission. Addressing this gap is essential for informing evidence-based discharge planning, secondary prevention strategies, and the development of targeted interventions to reduce avoidable hospital readmissions. By recognizing these preventable risk factors, healthcare providers can develop targeted prevention strategies and educational interventions tailored to stroke patients, ultimately aiming to reduce readmission rates. Furthermore, as the quality of stroke care continues to improve, the dynamics of risk factors influencing readmissions may evolve. Therefore, understanding the most influential and relevant risk factors is crucial for adapting care practices and optimizing patient outcomes in the post-stroke recovery process.[12-15]

This umbrella review aimed to (1) identify modifiable risk factors for 30-day and 1-year readmission after stroke and (2) develop an evidence-informed illustrative model describing their relationships with readmission.

Material and Methods

This umbrella review was conducted according to the methodological principles for umbrella reviews described in the Joanna Briggs Institute (JBI) Manual for Evidence Synthesis and reported in accordance with the PRISMA 2020 statement.[10] The study was approved by the Ethics Committee of Mashhad University of Medical Sciences, Mashhad, Iran (**IR.MUMS.NURSE.REC.1402.004**).

Data Collection

A comprehensive literature search was conducted in PubMed, Web of Science (WoS), Scopus, Cochrane Library, Cumulative Index to Nursing and Allied Health Literature (CINAHL), and Google Scholar to identify eligible studies published from January 2004 to June 2024. The search

period was restricted to 2004 onwards because systematic reviews and meta-analyses examining stroke readmission and its associated risk factors began to emerge during this period, reflecting the growing emphasis on evidence synthesis and post-stroke care. Restricting the search to this timeframe ensured that the review captured contemporary evidence relevant to current clinical practice and healthcare systems.

The electronic search combined controlled vocabulary (e.g., MeSH terms in PubMed) and free-text terms related to stroke, hospital readmission, and modifiable risk factors. The complete search strategies, including database-specific syntax, Boolean operators, field tags, and controlled vocabulary, are provided in Supplementary File 1. Searches were adapted to the indexing system and search interface of each database.

Google Scholar was searched using the same key concepts adapted to its search interface. To maximize reproducibility while minimizing retrieval of non-relevant records, only the first 200 results sorted by relevance were screened, consistent with recommended practice for systematic reviews. Duplicate records identified across databases were removed using reference management software, followed by manual verification before title and abstract screening.

In addition, the reference lists of all included reviews were manually searched to identify potentially eligible studies that were not retrieved through the electronic database search.

Inclusion and Exclusion Criteria, and Screening

Eligible studies included reviews that investigated readmission among stroke survivors, including systematic reviews, meta-analyses, narrative reviews, and scoping reviews, published as full-text articles in English. Narrative and scoping reviews were included because preliminary screening indicated a limited number of systematic reviews and meta-analyses addressing modifiable risk factors for post-stroke readmission. Their inclusion enabled a more comprehensive synthesis of the available evidence and supported the identification of potentially modifiable factors for evidence-informed illustrative model development. However, the methodological quality of all included reviews was critically appraised before data synthesis.

The literature search, study selection, and eligibility assessment were independently performed by two reviewers. Duplicate records were removed prior to screening. Disagreements were resolved through discussion, and when consensus could not be reached, a third reviewer was consulted.

Methodological quality was independently assessed by two reviewers using AMSTAR II. AMSTAR II [9] classifies systematic reviews according to the presence of critical and non-critical

weaknesses, resulting in four confidence ratings: high, moderate, low, and critically low. Reviews rated as high or moderate confidence were included in the final synthesis, whereas reviews with low or critically low confidence were excluded.

Data Extraction

Data extraction included authors, publication year, study type, sample size, follow-up period, readmission rate, and associated risk factors. The primary outcome was the rate of readmission within 30 days and 1 year after discharge. Reporting was based on PRISMA guidelines.[10]

Data Synthesis

Data were synthesized using a narrative descriptive approach because of the methodological heterogeneity across the included reviews with respect to study design, follow-up period, and reported outcomes. Evidence from systematic reviews, meta-analyses, narrative reviews, and scoping reviews was integrated by identifying and comparing modifiable risk factors consistently reported across the included reviews. When available, effect estimates (odds ratios [ORs] and corresponding confidence intervals) reported in the original reviews were extracted and summarized; no additional quantitative pooling or meta-analysis was performed.

The extracted data were tabulated according to the first author, publication year, review type, review objective, sample size, follow-up period, readmission rate, and identified risk factors for 30-day and 1-year readmission after stroke. To develop the evidence-informed illustrative model, the identified modifiable risk factors were grouped into clinically related domains (e.g., cardiovascular comorbidities, treatment adherence, and post-discharge care) and mapped according to their reported associations with readmission. The evidence-informed illustrative model was developed through an inductive evidence-mapping process based on the synthesized findings of the included reviews. Following narrative synthesis, the identified modifiable risk factors were grouped into clinically related domains according to their reported associations with post-stroke readmission. Relationships among these domains were then visually organized to illustrate the evidence identified across the included reviews. The model was developed as an evidence-informed synthesis of the published literature and was not based on a predefined theoretical framework or validated through expert consensus or quantitative modeling. Accordingly, it should be interpreted as an illustrative representation of the available evidence rather than a validated evidence-informed illustrative model.

Results

A total of 1786 records were identified through the database search. After duplicate removal, 163 unique records remained for title and abstract screening, and 31 reviews met the eligibility criteria and were included in the umbrella review (Figure 1).

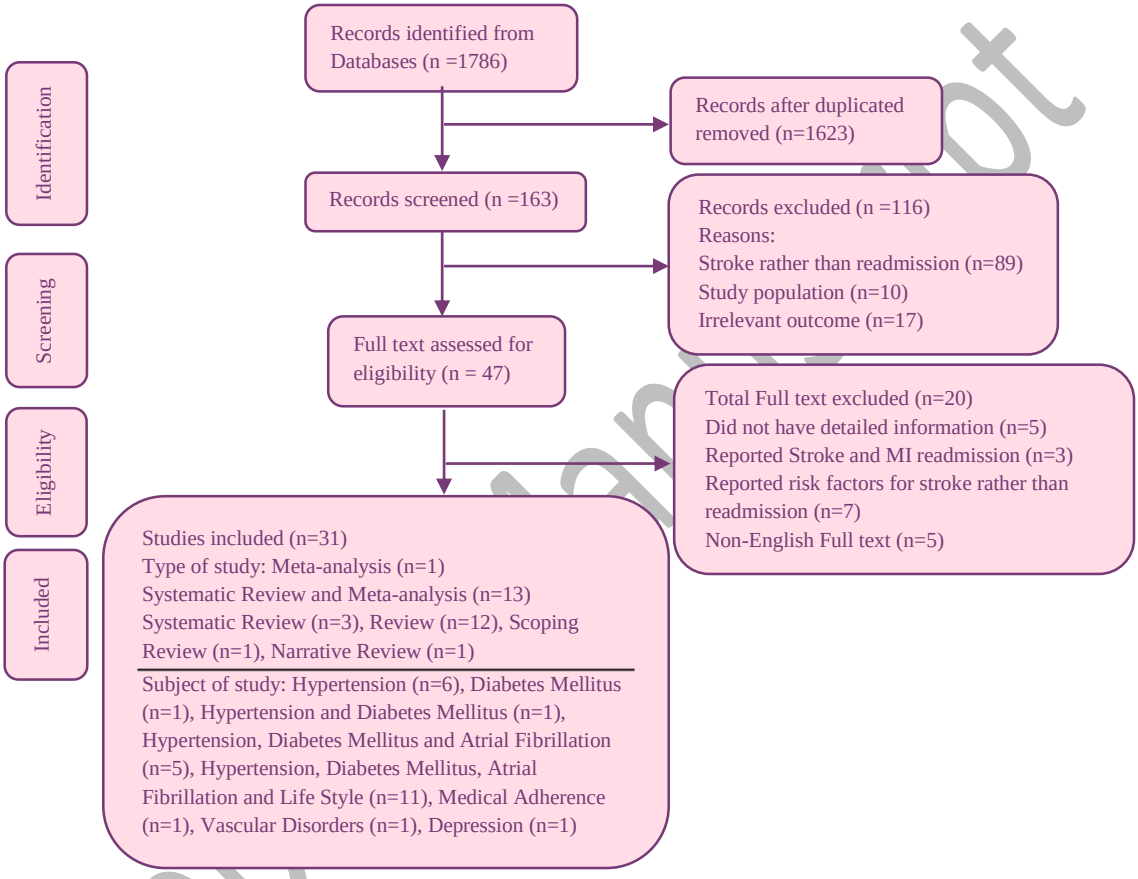

Figure 1. PRISMA flow diagram of the search process

Quality Evaluation

The included studies were of moderate quality (n= 25) or high quality (n= 6).

Results of descriptive analysis

Based on the included reviews, the reported 30-day hospital readmission rates after stroke ranged from 3.1% to 27.64%.[3,8,16-18] Hypertension was the most consistently identified modifiable risk factor for 30-day readmission and was frequently reported alongside diabetes mellitus and atrial fibrillation across the included reviews.[3,8,16,17] In addition, several reviews identified other potentially modifiable factors, including recurrent stroke, current smoking, malnutrition, urinary

tract infection, heart failure, coronary artery disease, lower socioeconomic status, longer hospital stay, poor post-stroke physical functioning, and increased numbers of previous hospitalizations.[3,8,16-18] Overall, the findings suggest that hypertension has the most consistent association with early readmission after stroke, whereas the reported associations for atrial fibrillation and diabetes mellitus were more variable across reviews and should therefore be interpreted with caution (Table 1).

Table 1. Summary of results of 30-day preventable risk factors of readmission

Authors (year)	**Review type and purpose**	**Sample Size** **Follow-up and [Readmission rate (%)]**	**Risk factors of readmission**
Lovett et al[17] (2004)	Meta-analysis To determine risk of recurrence by subtype of stroke	1709 30 days: [4.2]	Hypertension, diabetes mellitus, current smoking, and recurrent stroke (OR= 2.9).
Lichtman et al[8] (2010)	Systematic Review Identify and evaluate existing statistical models developed to compare hospital-level poststroke readmission rates and risk scores predicting readmission	9115 30-day all-cause: [6.5 -24.3] 30-day stroke-related: [7.4 - 9.4]	Diabetes, hypertension, longer hospital stay, poorer physical functioning after stroke, an increased number of previous hospitalizations, insurance type, stroke type, incident stroke, Malnutrition, Urinary tract infection, physician specialty, hospital characteristics/certification status.
Mohan et al[18] (2011)	Systematic Review and Meta-Analysis To estimate the pooled cumulative risk of stroke recurrence	40292 30-day: [3.1]	lower socio-economic status
Zhong et al[3] (2016)	Systematic Review and Meta-Analysis To evaluate the hospital readmissions, causes and risk factors after survival of acute stroke and TIA	253680 30-day: [17.4]	Diabetes, hypertension, atrial fibrillation, infection (19.9 %), coronary artery disease (CAD) (17.8 %) and recurrent stroke (16.0 %)
Deng et al[16] (2021)	Systematic Review and Meta-Analysis to identify risk factors for 30-day readmission in stroke survivors, with an attempt to improve post-discharge care and lower the 30-day readmission rate	1829964 30-day: [1.41 - 27.64]	Diabetes mellitus, hypertension, atrial fibrillation, heart failure.

After a follow-up period of one year, the identified risk factors included hypertension, with an OR ranging from 1.18 to 2.6,[3, 19-21] indicating a sustained risk for readmission. Atrial fibrillation and coronary artery disease (CAD) presented an OR between 0.567 and 2.4, suggesting variability in their impact on readmission risk over time. Diabetes mellitus was associated with an OR of 0.913 to 1.4, indicating a less clear association with readmissions.[3, 21] Additionally, lifestyle-related factors such as smoking were linked to an OR of 1.5 to 2.1,[21, 22] highlighting the importance of behavioral modifications in reducing readmission risk. Other significant factors included a body mass index (BMI) greater than 25 kg/m², poor dietary adherence (specifically non-adherence to the Mediterranean diet and excessive salt intake greater than 2.4 g/day), and post-stroke physical inactivity, which had an OR ranging from 1.14 to 2.1[23-27] (Table 2).

Table 2. Summary of results of 1-year preventable risk factors of readmission

Authors (year)	**Review type and purpose**	**Sample Size Follow-up and [Readmission rate (%)]**	**Risk factors**
Egido[26] (2005)	Review To review the currently available data, attempt to identify new predictors, and discuss the possible benefits of modifying these predictive factors.	- 1-year: [4]	Diabetes is the most consistent risk factor for recurrence in different studies, while control of hypertension has been shown to be effective in the prevention of recurrences
Lichtman et al[8] (2010)	Systematic Review Identify and evaluate existing statistical models developed to compare hospital-level poststroke readmission rates and risk scores predicting readmission	9115 1-year all-cause: [30.0 - 62.2] 1-year stroke-related: [10.5- 31.1]	Diabetes, hypertension, longer hospital stay, poorer physical functioning after stroke, an increased number of previous hospitalizations, insurance type, stroke type, incident stroke, Malnutrition, Urinary tract infection, physician specialty, hospital characteristics/certification status
Mohan et al[18] (2011)	Systematic Review and Meta-Analysis To estimate the pooled cumulative risk of stroke recurrence	40292 1-year: [11.1]	lower socio-economic status
Arima et al[27] (2011)	Systematic Review and Meta-Analysis The Perindopril Protection Against Recurrent Stroke Study (PROGRESS) trial focusing on BP-lowering treatment for secondary prevention of stroke	40292 Recurrence rate: don't reported	BP> 130⁄80 mm Hg in all patients with cerebrovascular disease
Bettger et al[28] (2013)	Systematic Review Describes the rates, predictors and causes of readmission among stroke patients who received short-term inpatient and post hospital care	100681 1-year: [8.2-74.5]	Inpatient rehabilitation, length of stay, and self-care ability
Hankey et al[21] (2014)	Systematic Review and Meta-Analysis To describe separately the prognosis and predictors for early and long-term recurrent stroke and the strategies to prevent both types of strokes	73538 1-year: [11.1]	Hypertension (OR=2.6), diabetes (OR=1.4), smoking (OR=2.1), alcohol intake >30 drinks per month (OR=1.5), previous symptomatic vascular disease (stroke, myocardial infarction, or peripheral arterial disease (OR=2.4)), unstable vascular disease (several recurrent recent ischemic events of the brain, including the capsular warning syndrome), embolic sources and causes (atrial fibrillation, or stroke caused by embolism from the heart or large arteries), and possibly cerebral microbleeds
Zhong et al[3] (2016)	Systematic Review and Meta-Analysis	253680 1-year: [42.5]	Recurrent stroke (19.4 %), infection (19.3 %) and CAD (16.3 %).

Authors (year)	Review type and purpose	Sample Size Follow-up and [Readmission rate (%)]	Risk factors
	To evaluate the hospital readmissions, causes and risk factors after survival of acute stroke and TIA		No significant differences were identified when comparing other risk factors such as diabetes mellitus (OR=0.913), hypertension (OR:1.185), atrial fibrillation (OR:0.567)
Chin et al[23] (2018)	Scoping review comprehensively focuses on prevalence, risk factors, and secondary prevention for stroke recurrence identified in South, East, and Southeast Asian countries	20333 1-year: [2.2-25.4]	Pathophysiological factors (hypertension, ankle-brachial pressure index, atherogenic dyslipidemia, diabetes mellitus, metabolic syndrome, and atrial fibrillation) and lifestyle factors (obesity, smoking, physical inactivity, and high salt intake)
Wajngarten et al[29] (2019)	Review Management of arterial hypertension to prevent the first episode and the recurrence	- 1-year: [4]	The systolic BP>130 mmHg
Gorelick et al[30] (2019)	Review To discuss recent United States (US)-based guidance statements on the management of BP in stroke according to stroke type and stage of stroke	795000 1-year: [25]	BP>130/80 mm Hg
Kolmos et al[5] (2021)	Systematic Review and Meta-Analysis To identify subtype-specific stroke recurrence and associated risk factors over time	52436 [5.7-51.3]	Hypertension, diabetes mellitus, atrial fibrillation previous transient ischemic attack, and high stroke severity were independent risk factors for recurrence

Model development

Figure 2 shows the relationship between the preventable risk factors contributing to stroke readmissions in the evidence-informed illustrative model according to descriptive analysis. Based on the integration of descriptive data, the model was developed. Lifestyle-related factors and treatment non-adherence were mentioned at the beginning as they could play an indirect role in readmissions. HTN was also highlighted as the most important cause in six articles. Other risk factors were displayed proportionally smaller and farther. Depression, cited in one study, was written lower than prior stroke and DM, although its OR was similar to that of CAD.

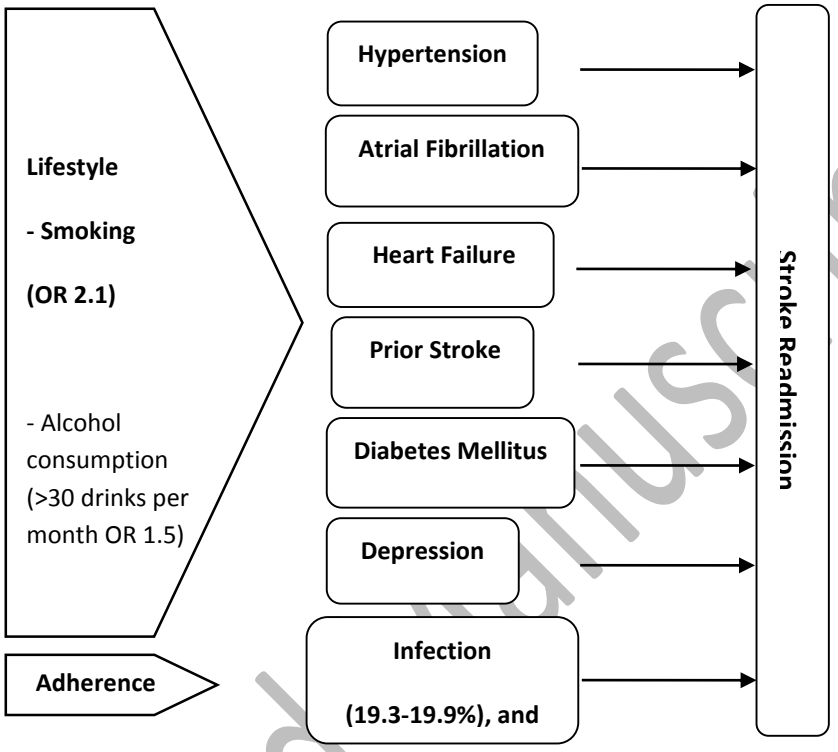

Figure 2. Evidence-informed conceptual model illustrating the modifiable risk factors associated with post-stroke readmission, developed through narrative synthesis of the included reviews.

Discussion

To our knowledge, this study is one of the first umbrella reviews specifically synthesizing evidence on preventable risk factors for 30-day and 1-year readmissions after discharge among stroke survivors. Although previous reviews have identified several risk factors for post-stroke readmission, uncertainty remains regarding their relative importance and clinical implications. [3, 5, 6, 16, 18, 31-36] As stroke continues to be a leading cause of disability and mortality worldwide, synthesizing the available evidence may help inform targeted prevention strategies and improve post-discharge care.

Our umbrella review identified hypertension (HTN), atrial fibrillation (AF), diabetes mellitus (DM), prior stroke, coronary artery disease (CAD), depression, infections, lifestyle-related factors (e.g., smoking, alcohol consumption, obesity, and physical inactivity), and treatment non-adherence as the most consistently reported modifiable risk factors associated with hospital readmission after stroke across the included reviews. Although the strength of the reported associations varied among studies, hypertension was the factor most consistently associated with

readmission, whereas the evidence for atrial fibrillation and diabetes mellitus was less consistent across reviews. Compared with established risk factors for incident stroke, the factors associated with post-stroke readmission extend beyond traditional vascular risk factors to include post-discharge clinical complications (e.g., infections), treatment adherence, functional status, and continuity of care. These findings suggest that reducing readmission risk requires not only optimal management of vascular comorbidities but also comprehensive post-discharge care and secondary prevention strategies tailored to the needs of stroke survivors.

Comparison of readmission rates

The included reviews reported considerable variation in post-stroke readmission rates, ranging from 3.1% to 27.64% within 30 days and 2.2% to 74.5% within 1 year after discharge. This wide variability likely reflects differences in patient characteristics, stroke severity, healthcare systems, follow-up duration, and definitions of readmission across the included studies. These findings underscore the complexity of post-stroke readmission and highlight the importance of considering clinical and methodological heterogeneity when interpreting readmission rates across different settings. A systematic review found that variations in readmission rates could be attributed to differences in healthcare systems, access to care, and socioeconomic factors. [28] For instance, regions with integrated care models showed lower readmission rates, indicating that systemic factors play a critical role in patient outcomes. Improving vascular health throughout life may help prevent other risk factors that could potentially be avoided to minimize readmission rates.

Hypertension as a risk factor

It is important to note that studies from countries with high-quality healthcare and follow-up programs, such as Taiwan and Norway, may weaken the overall effect of HTN on stroke readmissions. For instance, the study by Tseng et al[37] showed a significantly lower HTN rate in the readmission group (45% vs. 55%), with an OR of 0.67. These results could be attributed to the comprehensive healthcare program for stroke survivors in Taiwan since 1998. However, this explanation remains speculative, as our review did not formally assess sources of heterogeneity across studies. This finding showed that post-discharge programs may help reduce hypertension as a risk factor aligns with research by Bjerkreim et al[36] which emphasized the importance of medication adherence and lifestyle modifications in managing hypertension post-stroke. They reported that structured follow-up programs significantly improved blood pressure control among stroke survivors, thereby reducing readmission rates.

Atrial fibrillation as a risk factor

AF was among the most frequently reported cardiovascular risk factors associated with post-stroke readmission; however, the strength of this association varied considerably across the included reviews. Although several reviews reported that AF was associated with an increased risk of recurrent stroke and hospital readmission, the reported effect estimates ranged from below to above unity (OR=0.567–2.4), indicating inconsistency in the available evidence. This heterogeneity may be explained by differences in patient characteristics, stroke severity, follow-up duration, healthcare systems, and, importantly, the quality of AF management across study settings. Variations in the timely initiation of anticoagulation therapy, treatment adherence, anticoagulation quality (e.g., time in therapeutic range for vitamin K antagonists), and the increasing use of direct oral anticoagulants may substantially influence the relationship between AF and readmission risk. Consequently, AF should be interpreted as a potentially important but context-dependent risk factor, with its impact likely modified by the effectiveness of post-discharge management and secondary prevention strategies.[37,39,40]

Prior stroke history as a risk factor

Prior stroke history is a significant predictor of readmission. Patients with a history of stroke have been shown to have 1.33 times higher odds of being readmitted compared to those experiencing a stroke for the first time.[3,16] This increased risk is likely due to the accumulation of risk factors, including worse vascular conditions, older age, and multiple comorbidities and the potential for recurrent strokes.[41,42]

Diabetes mellitus as a risk factor

DM was frequently identified as a modifiable risk factor for post-stroke readmission across the included reviews, although the reported strength of the association varied between studies. Poor glycemic control may contribute to recurrent hospitalizations by increasing the risk of vascular complications, delaying functional recovery, and reducing the effectiveness of secondary prevention strategies. In addition, inadequate diabetes self-management and suboptimal adherence to treatment following hospital discharge may further increase the likelihood of readmission.[6, 38, 39]

While diabetes is also an established risk factor for primary stroke incidence, its role in post-stroke readmission should be considered separately. Previous studies have reported odds ratios ranging from 0.75 to 6.3 for the association between diabetes and incident stroke, with higher risks observed among individuals with type 1 diabetes.[38] These findings primarily reflect the contribution of chronic hyperglycemia to endothelial dysfunction and accelerated atherosclerosis, which increase the risk of an initial cerebrovascular event rather than readmission after stroke. Furthermore, poor pre-stroke glycemic control (HbA1c >8.4%) has been associated with worse

ischemic and hemorrhagic stroke outcomes, potentially contributing to greater disability and a higher risk of subsequent hospitalization.[40]

Taken together, the available evidence suggests that diabetes is an important, although not uniformly consistent, risk factor for post-stroke readmission. Optimizing glycemic control, strengthening diabetes self-management, and ensuring adherence to evidence-based secondary prevention strategies may help reduce the risk of readmission among stroke survivors.

Coronary artery disease (CAD) as a risk factor

CAD was identified as a potential risk factor for post-stroke readmission in several included reviews; however, the evidence was less consistent than for hypertension. Zhong et al. reported an overall OR of 1.45 for the association between CAD and stroke readmission, although this finding did not reach statistical significance.[3] Similarly, Deng et al. found that the OR for CAD was greater than 1, but the association was not statistically significant, possibly because the available studies were limited to relatively short follow-up periods (≤1 year).[16] Conversely, some studies reported ORs below 1.0, suggesting a potential protective association.[3] This variability may reflect differences in patient characteristics, CAD severity, post-discharge management, and secondary prevention practices across study settings.

While CAD is also a well-established risk factor for primary and recurrent stroke, this evidence should be distinguished from its association with post-stroke readmission. Previous longitudinal studies have shown that individuals with CAD have an increased long-term risk of stroke, with reported ORs of 1.8 over 7 years and 2.32 over 5 years.[43-45] These findings primarily reflect the shared pathophysiological mechanisms of atherosclerosis and vascular dysfunction underlying incident cerebrovascular events rather than hospital readmission after stroke.

The inconsistent findings regarding CAD and post-stroke readmission may indicate that the relationship is influenced by the duration and quality of secondary prevention following discharge. Patients with established CAD often receive intensive cardiovascular risk management, including antithrombotic therapy, lipid-lowering treatment, and structured follow-up, which may improve treatment adherence and self-care and partially offset their baseline risk of readmission. Therefore, further studies with longer follow-up periods are needed to clarify the independent contribution of CAD to post-stroke readmission.

Infections as a risk factor

Infections, particularly pneumonia and urinary tract infections, were consistently identified as common complications associated with post-stroke readmission across the included reviews.

Zhong et al. reported that infections accounted for approximately 19.9% of readmissions among stroke survivors, highlighting their substantial contribution to post-discharge morbidity.[3] Rather than acting as independent vascular risk factors, infections may precipitate neurological deterioration, functional decline, and prolonged hospitalization, thereby increasing the likelihood of subsequent readmission. Early detection, appropriate antimicrobial treatment, vaccination where indicated, and standardized post-discharge surveillance may therefore play important roles in reducing infection-related readmissions.[46-49]

Depression as a Risk Factor

Depression was identified as a potentially modifiable contributor to post-stroke readmission, although quantitative effect estimates were not consistently reported across the included reviews. Depression may adversely affect motivation, participation in rehabilitation, medication adherence, and self-management behaviors, ultimately increasing the risk of recurrent hospitalization.[50, 51] Given its high prevalence after stroke, routine screening and timely psychological interventions should be considered integral components of comprehensive post-stroke care.

Lifestyle-Related Factors

Several lifestyle-related factors were identified across the included reviews, although the strength of evidence differed between individual behaviors. Current smoking was reported as a modifiable risk factor for readmission and recurrent vascular events, likely because of its adverse effects on endothelial function, thrombosis, and atherosclerotic progression.[17] Excessive alcohol consumption has also been associated with poorer cardiovascular outcomes and reduced adherence to secondary prevention strategies. Obesity and physical inactivity may contribute indirectly to readmission by worsening cardiovascular risk profiles, limiting functional recovery, and increasing the burden of comorbid conditions. Although quantitative effect estimates for these lifestyle factors were not consistently available, the overall evidence supports comprehensive lifestyle modification including smoking cessation, moderation of alcohol intake, weight management, and regular physical activity as an essential component of secondary stroke prevention.[52,53]

Non-adherence to Treatment as a Risk Factor

Treatment non-adherence emerged as an important modifiable factor associated with post-stroke readmission, although quantitative estimates were inconsistently reported across the included reviews. Failure to adhere to prescribed medications, risk-factor monitoring, rehabilitation programs, or scheduled follow-up may reduce the effectiveness of secondary prevention and increase the risk of recurrent hospitalization.[54] Strategies that promote medication adherence,

patient education, caregiver engagement, and structured post-discharge follow-up may therefore contribute to reducing preventable readmissions and improving long-term outcomes.[55]

Overall, the evidence synthesized in this umbrella review suggests that reducing post-stroke readmissions requires a comprehensive approach that extends beyond management of vascular risk factors alone. The evidence-informed conceptual model developed in this review highlights the interplay between cardiovascular comorbidities, post-stroke complications, lifestyle behaviors, and treatment adherence, providing an illustrative framework to inform future intervention development and research.

Evidence-Informed Illustrative Model

The evidence-informed illustrative model presented in Figure 2 summarizes the modifiable risk factors for post-stroke readmission identified across the included reviews and provides a practical framework for informing post-discharge care. Rather than depicting causal pathways or validated relationships among variables, the figure synthesizes the available evidence by highlighting the most consistently reported modifiable risk factors associated with hospital readmission. Accordingly, it may assist clinicians and healthcare planners in prioritizing preventive strategies within comprehensive secondary prevention programs.

To operationalize the findings summarized in Figure 2, targeted interventions should focus on optimizing hypertension management, improving treatment adherence, promoting healthy lifestyle behaviors, preventing post-stroke complications, and strengthening coordinated post-discharge care. Evidence from previous studies suggests that comprehensive post-discharge interventions addressing modifiable risk factors can reduce hospital readmission rates by approximately 26% to 44% over a six-month follow-up period.[56-60] Although the illustrative model may help guide intervention planning and future research, its proposed relationships have not been empirically validated and should therefore be interpreted as an evidence-informed synthesis rather than a theoretical or predictive model.

Limitations

This study has several limitations inherent to the umbrella review methodology. First, publication bias may have influenced the findings because studies reporting negative or inconclusive results are less likely to be published, potentially limiting the comprehensiveness of the available evidence. Second, the included reviews varied in methodology, follow-up duration, and study quality, resulting in considerable heterogeneity that complicated evidence synthesis.[3,16] In addition, another inherent limitation of umbrella reviews is the potential overlap of primary studies across the included systematic reviews and meta-analyses. Such overlap may lead to double-counting of individual studies and overestimation of the consistency or magnitude of associations for shared risk factors. Because the degree of overlap was not formally quantified

(e.g., using a Corrected Covered Area analysis), this should be considered when interpreting the findings.

Furthermore, some included reviews contained inconsistencies in the reporting or calculation of effect estimates. For example, discrepancies in the reported odds ratios in Zhong et al.[3] required verification and recalculation using the published data. Although these issues were addressed during data extraction, they highlight the importance of careful interpretation of evidence synthesized from secondary sources. Finally, residual confounding, particularly by stroke severity and other clinical characteristics that were not consistently adjusted for across the included reviews, may have influenced the reported associations between modifiable risk factors and hospital readmission. Therefore, the evidence-informed illustrative model presented in this review should be interpreted as a synthesis of the available literature rather than a validated predictive framework. Future high-quality systematic reviews and prospective studies with standardized outcome definitions and longer follow-up periods are needed to further clarify the relationships between modifiable risk factors and post-stroke readmission.

Conclusion

This umbrella review synthesized the available evidence on modifiable risk factors associated with hospital readmission among stroke survivors. Hypertension emerged as the most consistently reported modifiable risk factor, whereas the evidence for atrial fibrillation, diabetes mellitus, and coronary artery disease was more heterogeneous across the included reviews. In addition to cardiovascular comorbidities, post-stroke complications, treatment non-adherence, and lifestyle-related factors were identified as potentially important contributors to readmission.

The evidence-informed illustrative model developed in this review summarizes the relationships among these modifiable risk factors and provides an integrated overview of the available evidence. Although the model is intended as an illustrative synthesis rather than a validated conceptual framework, it may help inform future research and support the design of comprehensive post-discharge care strategies targeting multiple modifiable risk factors.

Given the methodological heterogeneity of the included reviews and the variability in reported effect estimates for several risk factors, the findings should be interpreted with appropriate caution. Future research should include high-quality systematic reviews and prospective longitudinal studies with standardized definitions of readmission, longer follow-up periods, and more rigorous adjustment for important confounders, including stroke severity, to further clarify the independent contributions of modifiable risk factors to post-stroke readmission.

Acknowledgments: The authors gratefully acknowledge the financial support for this work that was provided by Faculty of Nursing and Midwifery at Mashhad University of Medical Sciences.

We would like to thank the Deputy of Research at Mashhad University of Medical Sciences for funding the current project (No: 4011904).

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Conflict of Interest

The authors declare that they have no conflicts of interest.

Data Availability

All data generated or analyzed during this study are included in this article.

Ethical Issues

This article is the result of a research proposal (ID: IR.MUMS.NURSE.REC.1402.004), and approved by the ethics committee of Mashhad University of Medical Sciences.

Funding: The financial support of the University's Research Vice-Chancellor is hereby appreciated (No: 4011904).

Research Highlights

What is the current knowledge?

- Preventable risk factors such as AF, HTN, DM, and infections have been reported as important contributors to post-stroke hospital readmission.
- Identifying modifiable risk factors for readmission is essential for informing secondary prevention strategies and improving post-discharge care for stroke survivors.

What is new here?

- This umbrella review synthesizes evidence from existing reviews to identify the most consistently reported modifiable risk factors associated with 30-day and 1-year post-stroke readmission.
- An evidence-informed illustrative model was developed to summarize the relationships among modifiable risk factors associated with post-stroke readmission and to provide an integrated overview of the available evidence.
- Hypertension was the most consistently reported risk factor across the included reviews, whereas the reported associations for atrial fibrillation and diabetes mellitus were more heterogeneous, highlighting the need for further high-quality longitudinal research.

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