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Contemporary Statistics of Acute Ischemic Stroke and Transient Ischemic Attack in 2021: Insights From the CRCS-K-NIH Registry

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ABSTRACT

This report presents the latest statistics on the stroke population in South Korea, sourced from the Clinical Research Collaborations for Stroke in Korea-National Institute for Health

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(CRCS-K-NIH), a comprehensive, nationwide, multicenter stroke registry. The Korean cohort, unlike western populations, shows a male-to-female ratio of 1.5, attributed to lower risk factors in Korean women. The average ages for men and women are 67 and 73 years, respectively. Hypertension is the most common risk factor (67%), consistent with global trends, but there is a higher prevalence of diabetes (35%) and smoking (21%). The prevalence of atrial fibrillation (19%) is lower than in western populations, suggesting effective prevention strategies in the general population. A high incidence of large artery atherosclerosis (38%) is observed, likely due to prevalent intracranial arterial disease in East Asians and advanced imaging techniques. There has been a decrease in intravenous thrombolysis rates, from 12% in 2017–2019 to 10% in 2021, with no improvements in door-to-needle and door-to-puncture times, worsened by the coronavirus disease 2019 pandemic. While the use of aspirin plus clopidogrel for non-cardioembolic stroke and direct oral anticoagulants for atrial fibrillation is well-established, the application of direct oral anticoagulants for non-atrial fibrillation cardioembolic strokes in the acute phase requires further research. The incidence of early neurological deterioration (13%) and the cumulative incidence of recurrent stroke at 3 months (3%) align with global figures. Favorable outcomes at 3 months (63%) are comparable internationally, yet the lack of improvement in dependency at 3 months highlights the need for advancements in acute stroke care.

Keywords: Stroke; Statistics; Ischemic Stroke; Ischemic Attack, Transient; Hypertension; Demography; Korea

INTRODUCTION

The evolving trends in stroke care are critical for the strategic planning of health policies, effective resource allocation, and guiding future research. While international stroke organizations have periodically updated stroke statistics, the most comprehensive report available covers only up to 2020.[1,2] These updates have not addressed changes following the latest stroke guidelines,[3-5] nor have they considered the impact of the coronavirus disease 2019 (COVID-19) pandemic, which significantly disrupted stroke care systems during 2020–2021.[6] This highlights the need for current, real-world data to evaluate the effects of such disruptions and to guide adjustments in patient care strategies.

This study aimed to provide updated statistics for 2022, using data from a nationwide, prospective stroke registry. It explored various aspects including demographics, risk factors, clinical symptoms, treatment approaches during the hyperacute and acute phases, and patient outcomes. By doing so, it seeks to provide valuable insights for stroke care professionals, researchers, and policy-makers, contributing to the enhancement of stroke care quality.

ABOUT THESE STATISTICS

The Clinical Research Collaborations for Stroke in Korea-National Institute for Health (CRCS-K-NIH), established in 2008, is a nationwide, multicenter, prospective stroke registry. It aims to develop national guidelines, enhance the quality of stroke care, and reduce the stroke burden in Korea.[7,8] Details on the registry's history are provided in the Glossary under "History of the CRCS-K-NIH Registry" (**Appendix 1**). As of 2021, it encompasses 17 stroke

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centers across South Korea (**Fig. 1**) and compiles comprehensive clinical data on patients admitted with acute stroke or transient ischemic attack (TIA), as detailed in **Supplementary Table 1**. Generally, patients with hemorrhagic stroke are admitted to neurosurgical departments, therefore, the focus here is primarily on acute ischemic stroke (AIS) and TIA. A portion of patients with ischemic stroke are admitted to neurosurgical departments in Korea, especially in small or mid-sized hospitals. This subset of patients was not included in our study, which may limit the generalizability of our findings across all stroke care settings in the country. Future studies could aim to incorporate this data to provide a more comprehensive analysis of stroke care in South Korea.[9]

Data integrity is ensured through a protocol requiring initial registration within 24 hours of hospital admission, followed by de-identification of personal information and web-based ongoing data collection. Data is collected and registered by trained personnel, following standardized procedures and regular training, supported by a rigorous audit process for quality control, which has seen a query volume decrease from over 5,000 in 2018 to around 1,000 in 2021 (**Supplementary Fig. 1**). An independent outcome adjudication committee reviews outcome data monthly and conducts on-site investigations if needed.

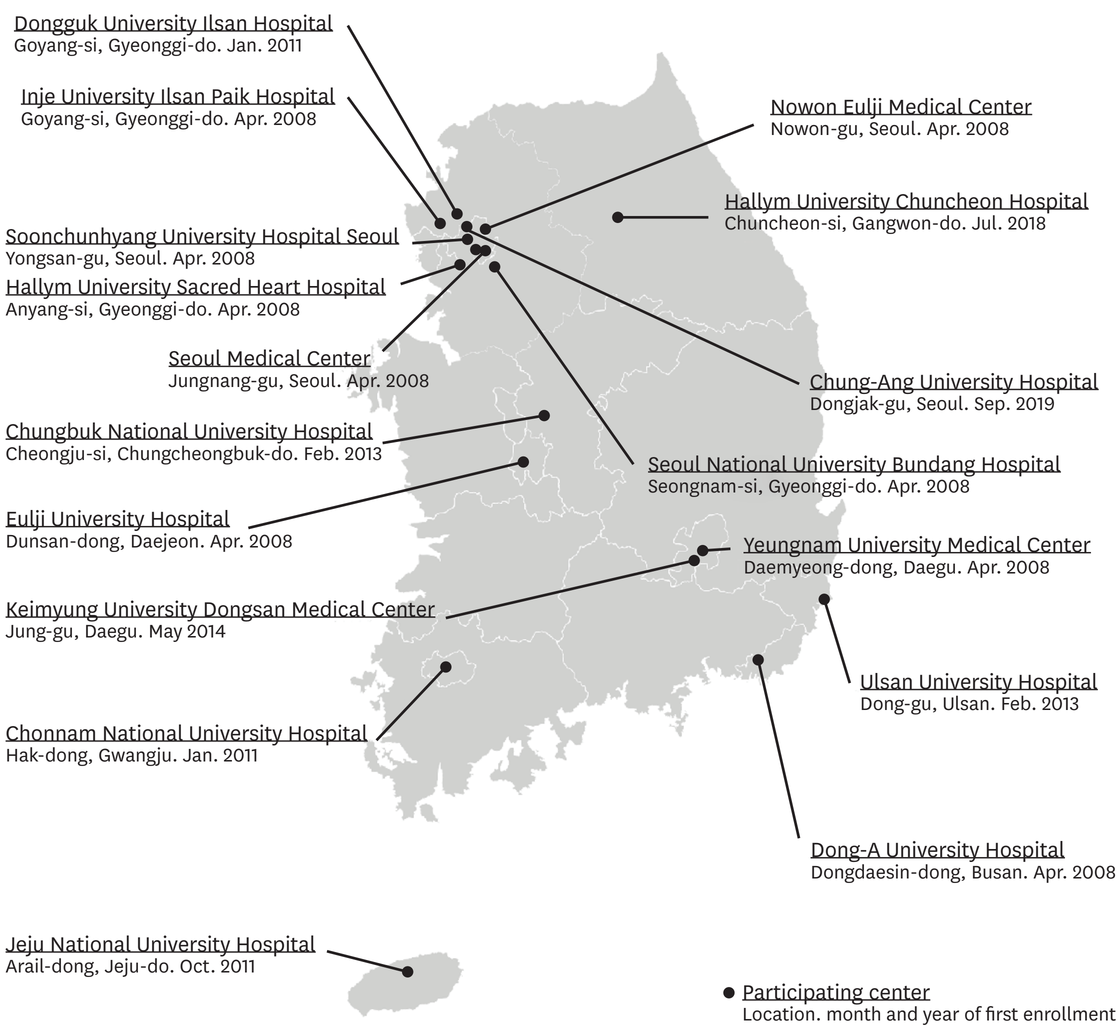

Fig. 1. Participating stroke centers and their geographic locations until 2021.

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The registry's geographical spread across 10 of the 17 first-tier administrative divisions ensures its representativeness (**Fig. 1**). The demographics and baseline characteristics closely match the national stroke audit data compiled by the Health Insurance Review and Assessment Service of 2018 (**Supplementary Table 2**), affirming the generalizability of the findings.[10]

We compared stroke statistics from 2021 with those from 2008–2020 to provide insights into contemporary stroke care. For recanalization therapy, owing to the significant impact of the COVID-19 pandemic on the accessibility of intravenous thrombolysis (IVT) and endovascular treatment (EVT),[11-15] the results were presented for pre-pandemic (2017–2019), and pandemic periods (2020 and 2021).[16-18]

Stroke cases in the CRCS-K-NIH registry for 2021

In 2021, the CRCS-K-NIH registry recorded 8,992 new cases of acute stroke or TIA. Of these, 8,855 (98.5%) were diagnosed as AIS or TIA, and 137 (1.5%) as hemorrhagic strokes. This addition brings the cumulative total to 97,326 cases from 2008 to 2021 (**Supplementary Table 3**, **Supplementary Fig. 2**).

Demographics and risk factors of acute ischemic stroke

In 2021, the CRCS-K-NIH registry reported a sex ratio of 1.5 for AIS or TIA cases (**Supplementary Table 4**), with men constituting 59.8% and women 40.2% (**Supplementary Table 5**). This ratio aligns with findings from other Asian countries such as Japan, Taiwan, and China,[19-22] and is higher than those observed in the United States and Sweden.[23,24] The lower prevalence of hypertension, diabetes, smoking, and obesity among Korean women compared to their American counterparts may contribute to these differences, indicating regional variances in vascular risk factors.[25-29]

Age-specific sex ratios show that men were more prevalent in the middle-aged group (55–64 years), while women were more common in the older age group (≥ 85 years), a finding consistent with prior research.[30] The mean age was 72.9 ± 13.4 years for women and 66.6 ± 12.9 years for men in 2021, both younger than counterparts in Japan and Sweden[20] but similar to those in the Greater Cincinnati/Northern Kentucky Stroke Study (**Supplementary Fig. 3**).[31] Considering these facts alongside Korea's life expectancy, which is comparable to Japan and Sweden and longer than the US,[32] highlight a higher incidence among young adults (20–54 years) compared to other countries.[33]

A 2-year increase in the mean age of AIS or TIA patients since 2008 reflects trends observed in Japan[20,34] but contrasts with stable or decreasing trends in European countries[35,36] and the US,[31] possibly indicating a rapidly aging population in Korea and Japan.

In 2021, hypertension was the most prevalent modifiable risk factor, affecting 67.4% of AIS cases, a figure consistent with international data (**Table 1**, **Fig. 2A**).[19,21,35] The prevalence of diabetes in AIS patients was 35%, which aligns with the United States (36%) but is higher than in Sweden, the UK, and Japan, where rates range from 23–28% (**Fig. 2B**). This disparity is notable considering that the prevalence of diabetes among the general Korean population over 20 years old is only 10% (13% in men, 8% in women), comparable to those countries (**Supplementary Table 6**). This underscores the importance of exploring the gap in diabetes management and associated vascular risk factors.

Table 1. Major modifiable vascular risk factors and pre-stroke management

Variables	Whole		Men		Women	
	2008–2020 (n = 86,637)	2021 (n = 8,855)	2008–2020 (n = 50,549)	2021 (n = 5,294)	2008–2020 (n = 36,088)	2021 (n = 3,561)
Hypertension, %	65.9	67.4	63.2	65.3	69.7	70.4
Newly diagnosed	8.9	9.6	10.2	11.2	7.2	7.5
Prior antihypertensives[a]	83.3	81.8	81	79.1	86.1	85.5
Diabetes, %	32.3	35.1	32.9	36.5	31.5	33.1
Newly diagnosed	12.7	12.6	13.7	13.7	11.3	10.9
Prior antidiabetics[a]	83.2	80.3	82.4	79.3	84.4	81.8
Dyslipidemia, %	30	35.6	29.1	34.3	31.3	37.5
Newly diagnosed	36.3	24.4	37.7	26.7	34.5	21.3
Prior statin[a]	80.4	75.6	79.5	75.0	81.4	76.4
Current smoker, %	23.6	21.1	37.0	33.0	4.6	3.5
Atrial fibrillation, %	19.7	19.3	17.4	16.9	23.0	22.9
Newly diagnosed	46.0	50.1	47.2	50.2	44.7	50.0
Prior anticoagulants[b]	39.6	57.1	37.9	54.5	41.3	60.0
Obese (BMI > 30 kg/m^2), %[c]	4.1	6.0	3.6	5.5	4.9	6.7
Medication before admission, %						
Antiplatelets	28.7	28.6	28.5	28.3	29	29.1
Statin	19.8	27.6	18.8	26	21.3	30.1

Based on 8,855 and 86,637 ischemic stroke cases registered in 2021 and 2008–2020, respectively.
BMI = body mass index.
[a]The denominator of the prior medication or anticoagulants use proportion in each risk factor is the number of patients having history of the risk factor.
[b]Anticoagulants include warfarin, apixaban, dabigatran, edoxaban, and ribaroxaban.
[c]In obese prevalence, due to missing values for height and weight, the number of patients in the population is following: 8,635 in 2021 and 84,732 in 2008–2020 of whole population; 5,166 in 2021 and 49,542 in 2008–2020 in men: 3,469 in 2021 and 35,190 in 2008–2020 in women.

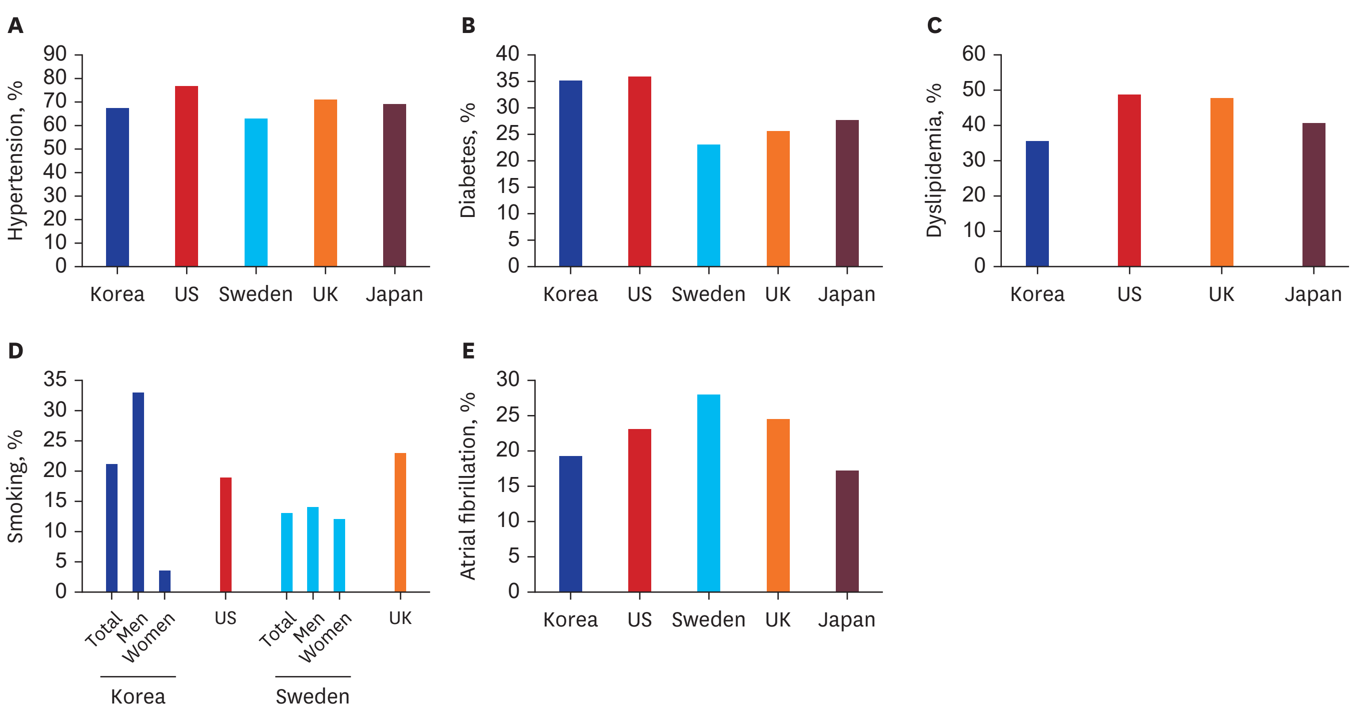

Fig. 2. Prevalences of vascular risk factors among acute ischemic stroke patients, categorized by country. Prevalence of hypertension (**A**), diabetes (**B**), dyslipidemia (**C**), current smoking (**D**) and atrial fibrillation (**E**).

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Dyslipidemia was observed in 35.6% of AIS patients, slightly lower than observed in other countries (41–49%) (**Fig. 2C**). This parallels the lower prevalence of hypercholesterolemia in the general Korean population compared to that in the US (**Supplementary Table 6**).

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In 2021, the prevalence of hypertension and dyslipidemia showed a slight increase compared to the levels observed during 2008–2010 (**Supplementary Table 7**), a trend also noted in the UK registry.[35] In contrast, the prevalence of diabetes in 2021 remained largely unchanged from 2008–2010, mirroring findings from both the US[37] and UK[35] registries.

A notable decrease was observed in newly diagnosed cases of dyslipidemia, dropping from 36.3% in 2008–2020 to 24.4% in 2021. This shift could be attributed to improved dyslipidemia awareness and detection among the Korean general population.[38] Comparatively, the proportion of patients receiving treatment prior to their index stroke for hypertension, diabetes, and dyslipidemia in Korea (**Table 1**) was on par with figures from the US and Japan.[20,37]

In 2021, the proportion of stroke patients with atrial fibrillation (AF) in Korea was 19%, aligning closely with Japan (17%)[22] and the UK (18%),[35] but was lower compared to the US (23%),[14] Germany (27%), and Sweden (28%).[15] Despite the aging of the Korean stroke population, the AF prevalence has remained stable since the mid-2010s (**Supplementary Table 7**). This stability could be partially attributed to the widespread use of direct oral anticoagulants (DOACs) since the mid-2010s, alongside an increase in patients receiving anticoagulants prior to their index stroke observed from 2014 to 2016.[39,40]

Nonetheless, it is noteworthy that half of the AF patients were still newly diagnosed post-stroke, a figure comparable to the global average of 43%.[41] This similarity underscores the need for more proactive AF detection and primary prevention strategies in individuals at high risk of AF.

In 2021, the prevalence of current smoking among stroke patients in Korea was 21%, slightly above that in the US (19%) and significantly higher than that in Sweden (13%) (**Supplementary Table 6**). However, there was a clear difference in the smoking rate between Korean men and women. It was 33.3% in men, which was higher than those in US counterparts (19.2% for Black men, 11.3% for White men), while the rate of 3.5% in women was substantially lower than those observed in US women (15.4% for Black women, 13.2% for White women).[42] These observations highlight the critical need for enhanced smoking cessation initiatives, particularly among Korean men, and vigilance to prevent an increase in smoking rates among Korean women.

The prevalence of obesity (body mass index > 30 kg/m^2) in the Korean stroke population stood at 6.0% in 2021, lower than 15.3% reported in Germany in 2001.[43] There was a 2% increase in obesity rates among both genders in 2021 compared to 2008–2020 (**Table 1**). Despite the lower prevalence of obesity in South Korea relative to western countries,[44] the rising trend, likely attributed to changes in dietary patterns, calls for increased awareness and intervention.

Clinical characteristics of acute ischemic strokes

In 2021, large artery atherosclerosis (LAA) emerged as the predominant subtype of AIS within the CRCS-K-NIH cohort, surpassing cardioembolism (CE) and small vessel occlusion (SVO) (**Table 2**, **Supplementary Fig. 4**, **Supplementary Table 8**). The LAA subtype accounted for 38% of cases, significantly exceeding the proportions observed in Japan (21%),[45] the UK (9%),[35] Canada (25%),[46] and the Czech Republic (28%).[47] This higher proportion may be attributed to several factors:

Table 2. Proportion of patients according to the TOAST classification in 2008–2020 vs. 2021

Variables	2008–2020, % (n = 80,034)	2021, % (n = 8,254)
Large artery atherosclerosis	35.2	38.2
Small vessel occlusion	18.2	17.9
Cardioembolism	21.2	19.5
Other determined etiology	3.4	4.6
Undetermined etiology - 2 or more	4.4	4.3
Undetermined etiology - Negative	8.9	9.7
Undetermined etiology - Incomplete work-ups	8.6	5.8

Based on 88,288 AIS cases registered between 2008 and 2021.
TOAST = Trial of ORG 10172 in Acute Stroke Treatment, AIS = acute ischemic stroke.

First, the greater prevalence of intracranial arterial disease among East Asians compared to Non-Hispanic Caucasians.[48]

Second, the adoption of less stringent criteria for defining the LAA subtype in Korea, including the use of an magnetic resonance imaging (MRI)-based algorithm for stroke subtype classification without a 50% stenosis threshold.[49]

Third, the increased utilization of advanced imaging techniques, such as high-resolution vessel wall MRI, facilitating more sensitive detection of arterial anomalies.[48]

In 2021, among patients with LAA stroke, 58% exhibited symptomatic intracranial arterial stenosis of over 50% or occlusion (**Fig. 3**, **Supplementary Table 9**). The prevalence of symptomatic intracranial steno-occlusion among AIS patients was 22%, which is consistent with findings from a sub-study of the Oxford Vascular Study.[50]

From 2008–2010 to 2021, there was a notable decline in the prevalence of symptomatic steno-occlusion of major cerebral arteries among patients with LAA stroke: from 70.5%

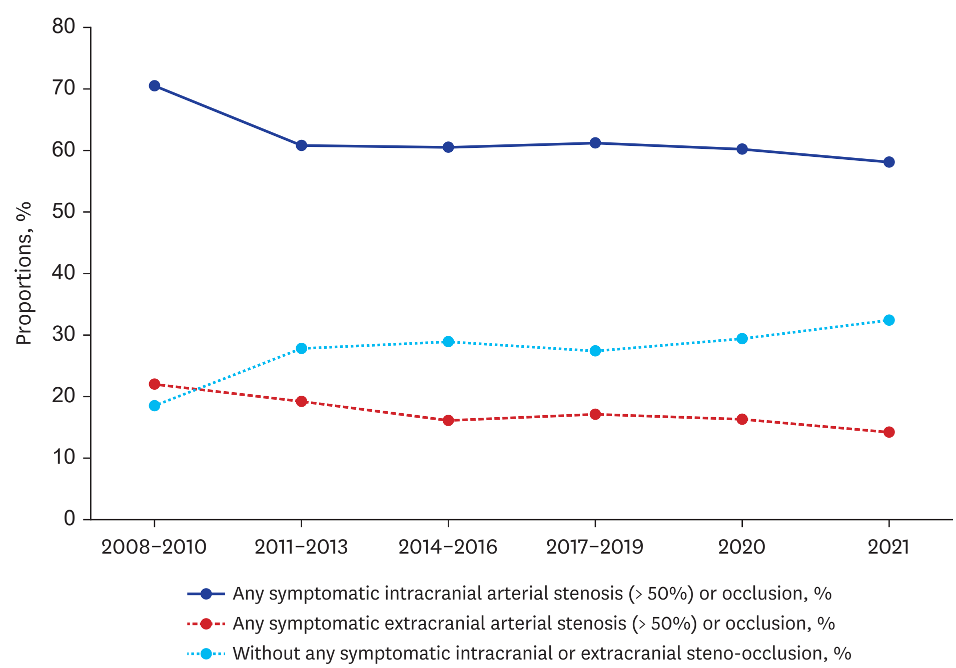

Fig. 3. Proportion of patients with intracranial, extracranial steno-occlusion or without steno-occlusion among those with large artery atherosclerosis stroke.

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to 58.1% for intracranial steno-occlusion and from 22.0% to 14.2% for extracranial steno-occlusion. This trend may be partially attributed to the increased use of lipid-lowering drugs in the general Korean population,[38] supported by the rising proportion of patients receiving statins prior to index stroke, as indicated in our data (**Table 1**).

Between 2008 and 2021, 18.0% of AIS patients in the CRCS-K-NIH registry were identified to have a high-risk cardio-embolic source, predominantly due to AF (**Supplementary Table 10**). Additionally, medium-risk cardioembolic sources were present in 6.0% of patients, such as patent foramen ovale and lone AF.

In 2021, the median National Institute for Health Stroke Scale (NIHSS) score among patients registered in the CRCS-K-NIH was 3, with an interquartile range (IQR) of 1–7 (**Fig. 4**), aligning with data from other countries.[24,37] Approximately 64% of patients experienced minor strokes (NIHSS scores of 0–4), a figure comparable to rates observed in the US[24] and the UK.[35] The proportion of minor strokes has increased over time, consistent with trends reported internationally.[19,20,35]

The majority (81.2%) of patients had a pre-stroke modified Rankin Scale (mRS) score of 0 (**Supplementary Tables 11**). The prevalence of patients with a history of stroke or TIA was 23% (**Supplementary Table 12**), closely mirroring Japan's 24%[20] but lower than the 31% documented in the US.[23] Among those with a history of stroke, 50% had a pre-stroke disability (pre-stroke mRS ≥ 1), compared to 15% among those without a stroke history (**Supplementary Table 13**).

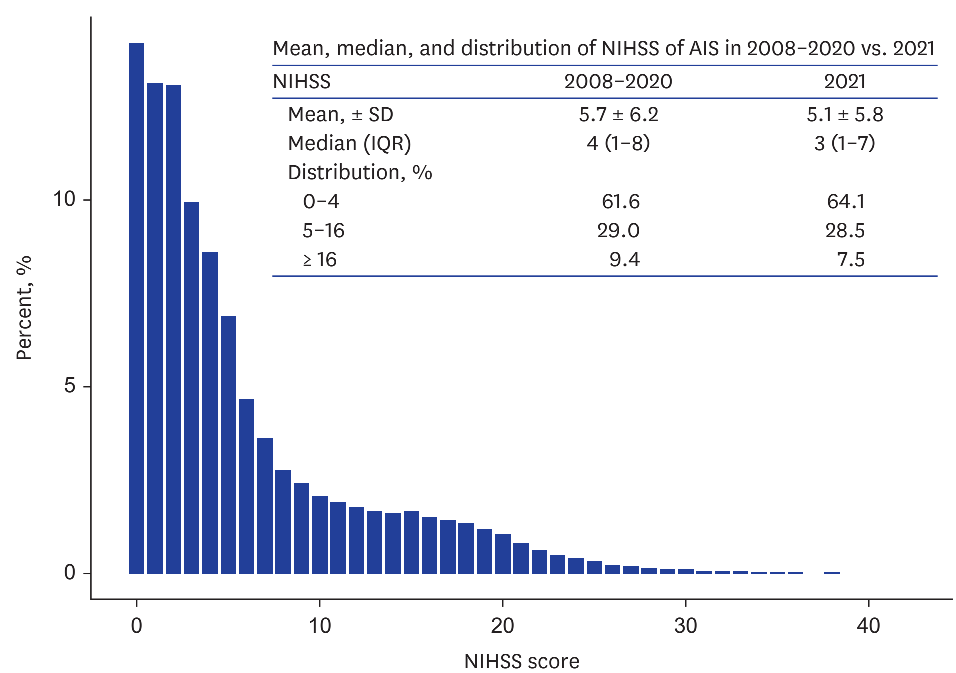

Fig. 4. NIHSS score at hospital arrival.
NIHSS = National Institute for Health Stroke Scale, AIS = acute ischemic stroke, SD = standard deviation, IQR = interquartile range.

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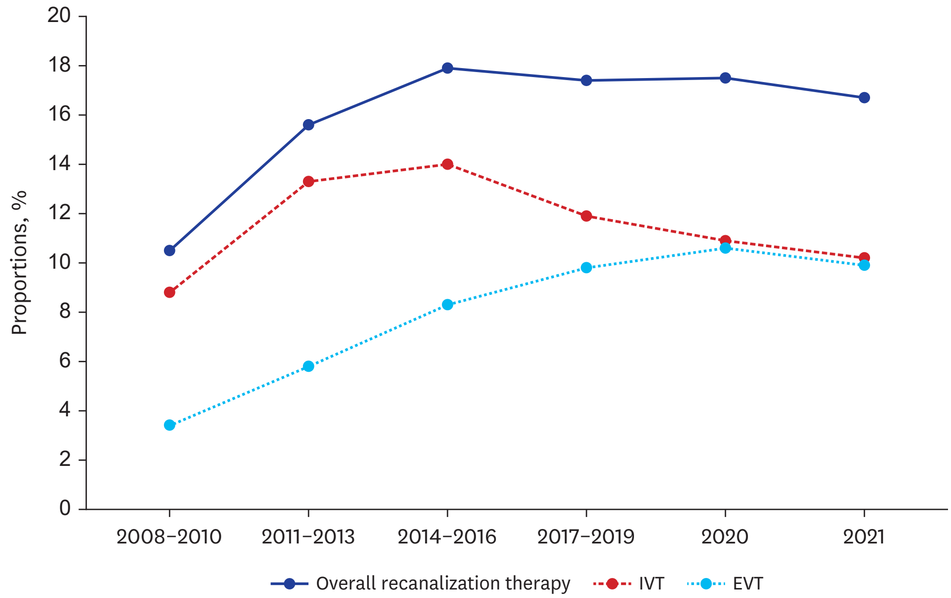

Fig. 5. Proportion of recanalization therapy administered from 2008 to 2021.
IVT = intravenous thrombolysis, EVT = endovascular treatment.

Recanalization therapy

Accessibility of recanalization therapies was notably hindered during the COVID-19 pandemic.[11-15] Accordingly, pre-pandemic data (2017–2019) and pandemic data (2020 and 2021) were analyzed separately to underscore these effects.

In the pre-pandemic period (2017–2019), the IVT rate of 11.9% was comparable to the US data (11%) in 2019,[23] yet lower than those in Germany (16%)[51] and Sweden (14%)[24] in the same year, but it was slightly higher than the rate in Japan (9%)[22] (**Fig. 5**, **Supplementary Table 14**). In contrast, the EVT rate in 2017–2019 was 9.8%, surpassing the rates in the US,[23] Germany,[51] and Sweden,[24] all at 7%.

The overall rate of recanalization therapy has plateaued since 2015, characterized by a declining IVT rate alongside an ascending EVT rate (**Fig. 5**, **Supplementary Table 14**). This pattern contrasts with other countries, where an increase in treatment rates has been observed.[52-54] The declining of IVT rate in Korea might be attributed to an inadequate number of primary stroke centers and a lack of human resources, even in hospitals where have stroke centers.

During the COVID-19 pandemic, a decline in the overall IVT rate was noted, falling to 10.9% in 2020 and further to 10.2% in 2021 (**Fig. 5**, **Supplementary Table 14**), aligning with trends observed in Japan,[22,55] Germany,[12] and China.[14] The proportion of patients receiving IVT within 4.5 hours of symptom onset also decreased, from 41% during 2014–2016 to 34% in 2021. Similarly, the EVT rate experienced a slight decline from 10.6% in 2020 to 9.9% in 2021, reflecting a global decrease in EVT procedures during the pandemic.[11]

There was no significant improvement in door-to-needle (DTN) or door-to-puncture (DTP) times since 2013 (**Fig. 6**, **Supplementary Table 15**). In 2021, the proportion of patients with a DTN time under 60 minutes was 77%, comparable to US data from 2019 and 2020,[13] yet falling short of the American Heart Association (AHA)'s target of 85%.[56] The median DTN

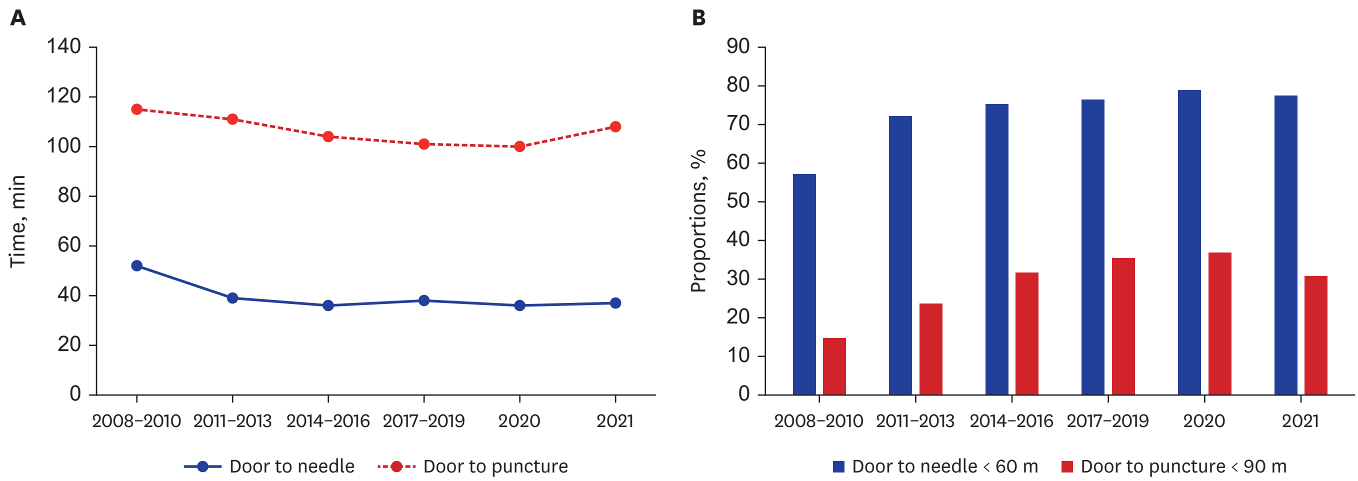

Fig. 6. Door-to-needle and door-to-puncture times from 2008 to 2021. Door-to-needle and door-to-puncture times (**A**) and the proportion (**B**) of patients achieving door-to-needle time within 60 minutes and door-to-puncture time within 90 minutes.

time remained around 37.0 minutes since 2014, in contrast to the ongoing improvements seen in the US, Canada, and Italy.[52-54]

In 2021, the median DTP time recorded was 108 minutes, with only 31% of cases achieving a DTP time under 90 minutes (**Fig. 6**, **Supplementary Table 15**), falling short of the AHA's target of 50%.[56] This median DTP time not only exceeds the AHA goal but is also longer compared to the US (97 minutes)[13] and Germany (74 minutes) data.[57] Our recent data indicate an increasing trend in median DTP time, underscoring a lack of progress in reducing treatment delays. The lack of improvement in the IVT rate and DTP time could be attributable to several key factors within the Korean healthcare system. One major issue is the shortage of stroke specialists, which hampers the ability to provide continuous care. Additionally, many hospitals, particularly outside of major urban centers, lack the necessary infrastructure to support a full-time (7-day, 24-hour) stroke response team. This limitation is critical for timely recanalization therapy, which is essential for optimal stroke outcomes. Further compounding these challenges are the financial and logistical constraints that prevent the expansion of dedicated stroke care facilities and the adoption of advanced stroke care protocols uniformly across the country.

Recanalization therapy-related quality indicators exhibited significant disparities across participating centers, as illustrated in **Supplementary Fig. 5** and **Supplementary Table 16**. Only 18% and 12% of hospitals met the AHA goal of a DTN time of less than 60 minutes in 85% of cases, and a DTP time of less than 90 minutes in 50% of cases, respectively.[56] These disparities across centers underscore the critical need for concerted efforts to enhance treatment timeliness.

The median time from the last known-well time or the first abnormal time to hospital arrival decreased steadily until 2019. However, there was an increase in these timeframes thereafter (**Supplementary Table 17**), likely due to the impact of the COVID-19 pandemic.

Acute management

In 2021, 66.7% of AIS patients received stroke unit (SU) care, a significant rise from the period of 2014-2016 (**Supplementary Table 18**). Although this rate surpasses Canada's 54%,[52] it falls short of Sweden's 93%.[24] Since 2017, the increase in SU care has plateaued, mirroring trends observed internationally and indicating a potential need for enhanced efforts to boost SU admissions.[24,52] This stagnation might be explained by the decreasing financial attractiveness of providing SU care in general hospitals, due to overall inflation and fixed reimbursement rates for such care. With the national stroke audit designating SU care as a key quality indicator in 2020, further enhancements in accessibility to SU care are anticipated.

Our data exhibit a high utilization rate of MRI-based imaging for AIS patients. During hospitalization, diffusion-weighted imaging (DWI), MRI, and MR angiography were performed in 95%, 87%, and 88% of AIS cases, respectively, significantly surpassing the MRI scan rates in the US (33%) and Sweden (35%) (**Supplementary Table 19**).[24,58] Additionally, perfusion MRI and computed tomography imaging were conducted in 31% and 6% of AIS patients, showcasing the comprehensive imaging approach adopted in Korea.

In 2021, AIS patients showed a decrease in average total cholesterol and low-density lipoprotein (LDL) levels at admission (**Supplementary Table 20**), aligning with a gradual rise in the use of lipid-lowering drugs among Korean individuals at risk of cardiovascular disease.[38] Initial glucose levels and hemoglobin A1c remained unchanged. However, average systolic and diastolic blood pressures at presentation have slightly increased, mirroring the rise in hypertension prevalence in Korea.[59]

In 2021, the use of transthoracic echocardiography (TTE) in our data reached 73%, surpassing Germany's 66%.[60] However, the use of transesophageal echocardiography (TEE) was notably lower at 4%, compared to Germany's 21% (**Supplementary Table 21**). The adoption of 24-hour Holter monitoring was 57%, exceeding Canada's 31%.[61] TEE and Holter monitoring were frequently used in evaluating patients with embolic stroke of undetermined source, being utilized in 85% and 71% of cases, respectively.

Antithrombotic drugs were administered to 94% of AIS patients within 48 hours of hospitalization in 2021 (**Supplementary Table 22**), aligning closely with the US rate of 97%.[23] Aspirin monotherapy was the most common treatment until 2016, but the combination of aspirin plus clopidogrel became the preferred regimen after 2017, used in 65% of cases by 2021 (**Fig. 7A**).

Upon discharge in 2021, aspirin plus clopidogrel was prescribed to 56% of all AIS patients (**Supplementary Table 23**), 64% of minor (NIHSS ≤ 3 points) stroke cares, and 47% of non-minor stroke cases (**Fig. 7B**, **Supplementary Table 24**). These rates are higher than those in the US; 47.0% and 42.6% for minor and non-minor stroke, respectively.[62]

In 2021, DOACs were prescribed at discharge for 75% of patients with CE stroke associated with AF (**Table 3**), a rate comparable to Sweden's 78%.[24] Additionally, DOACs were used acutely (within 48 hours of hospitalization) in 33% of these cases. It should be noted that previous evidence regarding the use of DOAC has been focused on stroke prevention in patients with AF or cryptogenic stroke. However, the role of DOACs is expanding, with emerging evidence supporting the benefits of their early initiation in patients with CE stroke and AF.[63] Notably, the use of DOACs for CE stroke without AF increased to 26% in 2021, while warfarin usage significantly dropped from 39% in 2008–2010 to 12% in 2021, indicating a significant shift in anticoagulation practices that merits further investigation.

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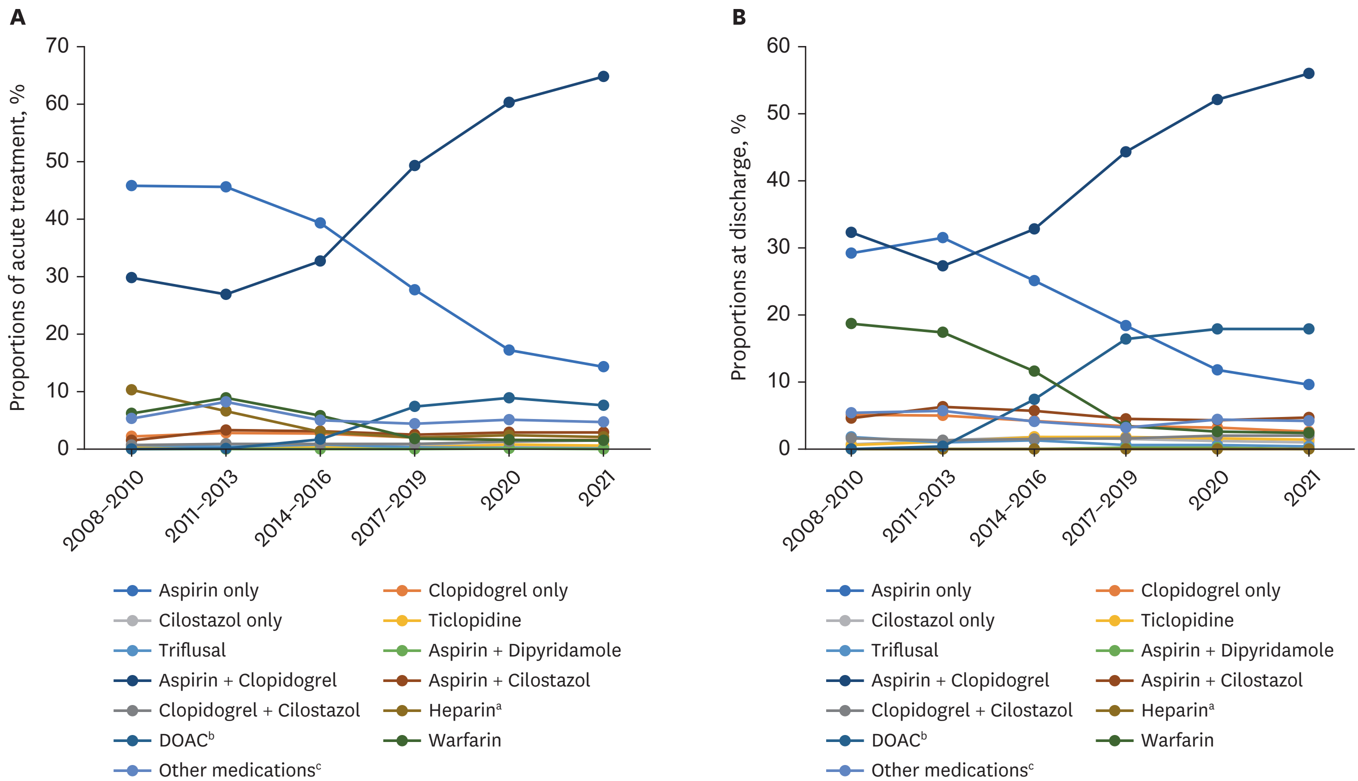

Fig. 7. Antithrombotic medications (multiple choices permitted) administered between 2008 and 2021. (**A**) Acute (within 48 hours of hospitalization) and (**B**) at-discharge antithrombotic medications.
[a]Both conventional and low-molecular weighted heparin.
[b]Apixaban, dabigatran, rivaroxaban, edoxaban.
[c]Other antiplatelets + other anticoagulants.

Table 3. Use of DOACs in cardioembolic stroke patients with and without atrial fibrillation

Variables	2008–2010	2011–2013	2014–2016	2017–2019	2020	2021
Cardioembolic stroke with atrial fibrillation[a]						
DOAC within 48 hr, %	0.0	0.2	6.7	32.8	38.0	32.5
DOAC at discharge, %	0.0	1.6	29.2	69.7	74.5	74.5
Warfarin at discharge, %	67.2	61.1	39.7	7.7	6.1	5.1
Cardioembolic stroke without atrial fibrillation[b]						
DOAC within 48 hr, %	0.0	0.1	0.6	5.2	6.5	6.7
DOAC at discharge, %	0.0	0.5	6.6	19.2	18.7	25.9
Warfarin at discharge, %	39.3	33.5	27.4	18.0	17.6	11.9

DOAC = direct oral anticoagulant.
[a]Based on 14,621 cardioembolic stroke patients with atrial fibrillation.
[b]Based on 3,971 cardioembolic stroke patients without atrial fibrillation.

In 2021, 91% of AIS patients were prescribed statins at discharge, a rate on par with the US (81%)[23] and Sweden (84%),[24] but significantly higher than Japan (47.1%).[22] This represents an increase from 72% in 2008–2010, mirroring the upward trend seen in Sweden,[24] where statin prescriptions rose from 64% in 2011 to 84% in 2022. Conversely, the US observed a stagnation in statin prescription rates, moving from 84.8% in 2007 to 81.2% in 2021.[23,64]

The increase in statin prescriptions in South Korea spanned all stroke subtypes, including LAA, CE, and SVO (**Supplementary Fig. 6**, **Supplementary Table 25**). Landmark studies demonstrating the benefits of early statin use, including “Effects of Very Early Use of Rosuvastatin in Preventing Recurrence of Ischemic Stroke (EUREKA)”[65] and “Target

Stroke to Target (TST)”[66] could lead to a lack of hesitation among clinicians in prescribing statins during the acute phase. Furthermore, comparative effectiveness research from CRCS-K-NIH revealed that CE patients who were treated with statins had better long-term outcomes, further supporting the widespread use of statins in CE as well.[67] Increasing statin prescription rate across subtypes of AIS might be explained, partly by positive results from above-mentioned studies that included Korean stroke patients.

In the 2021 CRCS-K-NIH data, decompressive surgery for AIS patients was performed at rates of 0.6% (**Supplementary Table 26**), notably lower than the 1.2% reported by comprehensive stroke centers in the US (2013–2018)[68] and 1.9% in Germany (2017).[69] This discrepancy may stem from differences in patient and family perceptions, cultural attitudes, and medical resource availability, highlighting areas for deeper exploration. In 2021, other surgical interventions like bypass surgery, endarterectomy, and angioplasty/stenting were carried out in 0.2%, 0.1%, and 1.6% of AIS patients, respectively.

Clinical outcomes after ischemic stroke

Since 2011, clinical outcomes for AIS patients have been systematically collected. The 2021 outcomes were analyzed in comparison to previous periods (2011–2019 and 2020). Specifically, a contemporary 1-year outcome was defined in 2020 for comparative analysis. In 2021, 13.4% of AIS patients (out of 8,254 cases) experienced early neurological deterioration (END) (**Table 4**), a rate that aligns closely with pooled meta-analysis data (13.8%)[70] and reports from China (14.1%).[71] The primary cause of END was stroke progression. Symptomatic hemorrhagic transformation (SHT) was observed in 0.8% of patients, with those undergoing IVT showing a SHT rate of 2.8%—comparatively on the lower spectrum against other studies (2.1–8.8%) and IVT trial findings (1.9–8.8%).[72,73] Among patients receiving EVT, the SHT rate was 4.5%, slightly below the rates reported in EVT trials (4.9–9.0%),[74-77] and a cohort study from the Netherlands (6%).[78] Furthermore, the proportion of patients achieving a favorable outcome (a mRS score of 0–2) at discharge stood at 61%, echoing results from the Japanese Stroke Data Bank (51%).[20]

Table 4. Events and outcomes during the hospitalization between 2008 and 2021

Variables	2011–2019 (n = 62,388)	2020 (n = 7,909)	2021 (n = 8,254)
Length of stay, median (IQR)[a]	7.0 (5.0–11.0)	7.0 (5.0–11.0)	7.0 (5.0–10.0)
Early neurological deterioration, %	13.9	13.4	13.4
Stroke recurrence[a]	1.2	1.4	1.0
Stroke progression[a]	10.1	9.9	10.2
SHT[a]	0.9	0.9	0.8
SHT among patients received IVT[b]	3.1	2.7	2.8
SHT among patients received EVT[c]	4.3	4.0	4.5
Other causes[a]	0.8	0.7	0.9
Unknown etiology[a]	0.8	0.5	0.6
Transient ischemic attack	0.1	0.1	0.0
Functional outcomes			
Discharge mRS, median (IQR)[a]	2 (1–4)	2 (1–4)	2 (1–4)
Proportions of favorable discharge mRS (0–2), %[a]	57.5	57.6	57.6
Proportions of excellent discharge mRS (0–1), %[a]	38.9	38.3	40.0

IQR = interquartile range, SHT = symptomatic hemorrhagic transformation, IVT = intravenous thrombolysis, EVT = endovascular treatment, mRS = modified Rankin Scale.
[a]Based on 88,288 ischemic stroke cases registered between 2011 and 2021.
[b]Based on 9,665 ischemic stroke cases received IVT between 2011 and 2021.
[c]Based on 6,664 ischemic stroke cases received EVT between 2011 and 2021.

Table 5. Cumulative incidences (%) of outcome events after stroke

Variables	2011–2019 (n = 62,388)	2020 (n = 7,909)	2021 (n = 8,254)
3-month events, %			
Composite outcome[a]	17.1	16.5	16.6
Stroke recurrence and progression	13.1	13.0	13.0
Stroke recurrence	3.3	3.2	3.2
Myocardial infarction	0.1	0.1	0.1
Vascular death	2.6	2.3	1.7
All-cause death	6.0	5.2	4.9
1-year events, %			
Composite outcome[a]	21.6	21.7	
Stroke recurrence and progression	14.7	14.8	
Stroke recurrence	5.0	5.1	
Myocardial infarction	0.1	0.1	
Vascular death	3.1	2.8	
All-cause death	10.0	9.6	

Based on 88,288 ischemic stroke cases registered between 2008 and 2021.
[a]Composite outcome: All-cause stroke + myocardial infarction + all-cause death.

In 2021, the CRCS-K-NIH registry reported a 3-month cumulative incidence of recurrent stroke at 3.2%, aligning closely with Germany's rate of 3.1% between 1998 and 2015 (**Table 5**).[79] Our 1-year cumulative incidence was 5.1%, comparable to Denmark's 4%[80] but lower than Germany's 7.5% (1998–2015)[79] and the US Medicare Fee-for-Service population's 7.6% (2016–2017).[81] These variations could be attributed to enhanced prevention strategies and differences in outcome collection methods. The 1-year mortality rate in Korea was 9.6% in 2020, significantly lower than Germany (21.0%),[79] Denmark (17%),[80] and Sweden (26% in 2013),[82] which might be explained by high accessibility to hospitalization for acute stroke even for patients with mild stroke and potential advances in stroke managements in Korea.

The subgroup analysis revealed that the 1-year cumulative incidence of recurrent stroke hospitalized in 2020 was highest among AIS patients with undetermined etiologies-two or more) at 10.1%, followed by LAA at 5.7%, CE at 5.1%, undetermined-negative at 4.7%, undetermined-incomplete at 4.1%, and SVO at 2.8% (**Supplementary Table 27**). This pattern is somewhat mirrored in the German data, where stroke recurrence was notably common among patients with undetermined etiologies, succeeded by CE, LAA, and SVO.[79] The pronounced recurrence in patients with undetermined etiologies-two or more underscores the need for further research. The comparatively lower recurrence rates in Korean patients with LAA and CE might reflect the recent adoption of dual antiplatelet therapy for non-CE strokes and DOACs for CE strokes, as opposed to the higher recurrence rates observed in Germany (7.7% in LAA and 8.0% in CE).[79]

In our cohort, 3-month and 1-year mRS scores were collected for 97% and 93% of patients, respectively. In 2021, 63% of all AIS patients achieved favorable outcomes (mRS 0–2) at 3 months, with 55% of those receiving IVT and 41% undergoing EVT achieving similar outcomes (**Tables 6** and 7, **Supplementary Fig. 7**). These rates align with those from other cohort studies[83-85] and clinical trials.[69,86] Excellent 3-month outcomes (mRS 0–1) were seen in 48% of all AIS patients and 39% of those receiving IVT, surpassing the 31% reported in a meta-analysis of IVT trials.[72] For 2021, favorable one-year outcomes were observed in 64% of AIS patients, with excellent one-year outcomes reported at 49% for 2020 (**Supplementary Fig. 8**).

In 2021, functional dependency at 3 months post-stroke, defined by a mRS score of 3–5, remained at 31%, unchanged from the period 2011–2019. This stability contrasts with

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Table 6. Functional outcomes at 3 months and 1 year after stroke

Variables	2011–2019 (n = 62,388)	2020 (n = 7,909)	2021 (n = 8,254)
3-month mRS, median (IQR)[a]	2 (1–3)	2 (1–4)	2 (1–4)
Proportions of favorable 3-month outcome (mRS of 0–2), %	62.8	63.2	62.6
Proportions of excellent 3-month outcome (mRS of 0–1), %	46.7	48.7	47.5
Proportions of 3-month functional dependency (mRS of 3–5), %	30.5	30.4	30.9
1-year mRS, median (IQR)[b]	1 (1–3)	1 (0–4)	
Proportions of favorable 1-year outcome (mRS of 0–2), %	64.4	63.7	
Proportions of excellent 1-year outcome (mRS of 0–1), %	51.0	49.4	
Proportions of 1-year functional dependency (mRS of 3–5), %	25.2	24.9	

IQR = interquartile range, mRS = modified Rankin Scale.
[a]Based on 76,222 ischemic stroke patients reported 3-month outcome between 2011 and 2021.
[b]Based on 65,048 ischemic stroke patients reported 1-year outcome between 2011 and 2020.

Table 7. Functional outcomes at 3 months and 1 year after stroke in patients received IVT and EVT

Variables	2011–2019 (n = 7,984)	2020 (n = 852)	2021 (n = 829)
IVT[a]			
3-month mRS, median (IQR)	2 (1–4)	2 (1–4)	2 (1–4)
Proportions of favorable 3-month outcome (mRS of 0–2), %	52.5	55.6	55.1
Proportions of excellent 3-month outcome (mRS of 0–1), %	36.6	42.9	39.3
EVT[b]			
3-month mRS, median (IQR)	3 (1–5)	3 (1–5)	3 (1–5)
Proportions of favorable 3-month outcome (mRS of 0–2), %	41.2	42.8	40.9
Proportions of excellent 3-month outcome (mRS of 0–1), %	27.8	31.4	29.9

IVT = intravenous thrombolysis, EVT = endovascular treatment, IQR = interquartile range, mRS = modified Rankin Scale.
[a]Based on 9,419 ischemic stroke patients received IVT and reported 3-month outcome between 2011 and 2021.
[b]Based on 6,484 ischemic stroke patients received EVT and reported 3-month outcome between 2011 and 2020.

improvements seen in England, where functional dependency decreased from 35% (2000–2003) to 27% (2012–2015) as defined by a Barthel index < 15, and in Sweden,[35] where it improved from 19% in 2011 to 15% in 2022, as measured by Activities of Daily Living scales.[24,87]

The median mRS scores at 3 months and 1 year have remained steady from 2018 to 2021. It was observed that higher median 3-month mRS scores were associated with female gender, older age, and CE stroke, aligning with findings from previous research.[30,88-90]

SUMMARY

- The sex ratio of 1.5 favoring men over women in Korea aligns with other Asian countries and is notably higher than that in the US and Sweden. The difference between Korea and the US could be attributed to the lower prevalence of hypertension, diabetes, smoking, and obesity among Korean women.

- The average age for patients with AIS and TIA in this cohort was 73 years for women and 67 years for men. These ages are lower than those reported in Japan but are comparable to the United States. Considering these facts alongside Korea's life expectancy being similar to Japan's and higher than that of the US highlights the earlier onset of stroke in Korea. Since 2008, there has been a rising trend in the average age of the stroke population, a trend that mirrors data from Japan.

- Hypertension, present in 67%, was the most common risk factor. comparable to the prevalence in other countries. The diabetes prevalence in our cohort (35%) was higher than that in Sweden, the UK, and Japan, despite the prevalence in general population being lower than these countries. Dyslipidemia prevalence (35.6%) was marginally lower than in other countries and newly diagnosed dyslipidemia decreased from 2008–2020 to 2021.

- The prevalence of AF in AIS patients was 19%, lower than that in western countries, which could reflect the effective stroke prevention strategies for AF. Nonetheless, a significant number of AF cases are diagnosed only after a stroke has occurred.

- The smoking rate among AIS patients in Korea stands at 21%, significantly higher than in the US and Sweden, especially among Korean men, underscoring the urgent need for more aggressive smoking cessation initiatives.

- The proportion of LAA at 38% exceeds those observed in the UK, Japan, and Canada. This discrepancy may be due to higher prevalence of intracranial arterial disease among East Asians, less stringent definition of LAA, and the widespread use of advanced imaging techniques. The prevalence of symptomatic intracranial or extracranial steno-occlusions (> 50%) has declined from 2008–2010 to 2021, a trend that cloud be partly attributed to the increased use of lipid-lowering drugs.

- About two-thirds of patients were presented with minor stroke (NIHSS score of 0–4) that the proportion has increased from 2008–2010 to 2021, similar to other countries. The median NIHSS score was 3 in 2021, also similar to other countries.

- In the pre-pandemic (2017–2019), the IVT rate was 11.9% which was lower than that in Germany and Sweden, and it decreased from 14.0% during 2014–2016. The EVT rate (9.8%) was higher than other countries and saw a significant rise from 3.4% in 2008–2010. During the pandemic, a decreasing trend in IVT and EVT was noted, reflecting pandemic influences similar to global trends.

- Since 2014, the median DTN time has stayed constant at approximately 37 minutes, unlike the continuous improvements observed in other countries. In 2021, the median DTP time was recorded at 108 minutes, showing an upward trend and highlighting a stagnation in efforts to minimize treatment delays.

- Until 2016, aspirin monotherapy was the predominant acute treatment, but since 2017, aspirin plus clopidogrel has become the preferred regimen, being utilized in 65% of cases by 2021. Upon discharge, this dual therapy became the most common, prescribed to 64% of minor stroke patients and 47% of those with more severe strokes in 2021.

- Among CE stroke patients with AF, 75% were prescribed DOACs, with 33% receiving within 48 hours. Notably, warfarin usage significantly declined from 39% in 2008–2010 to 12% in 2021 and DOACs were used in 26% in 2021 among CE stroke patients without AF. Additionally, statins were prescribed at discharge to 91% of patients, indicating an upward trend in their use across all AIS subtypes.

- END occurred in 13%, a rate comparable to that found in meta-analysis data. SHT rates among patients who received IVT and EVT were 2.8% and 4.5%, respectively, both of which are relatively lower than the rates reported in other studies.

- In 2021, the crude 3-month cumulative incidence of recurrent stroke was 3.2%, aligning with historical figures from Germany. However, the 1-year recurrence rate of 5.1% was somewhat lower than those reported in Germany and the US until the mid-2010s, potentially reflecting advancements in stroke prevention strategies. The pronounced one-year recurrence in patients with undetermined etiologies-two or more (10.1%) draws our attention.

- The proportion of 3-month mRS 0–2 was 63%, comparable to other cohort studies and IVT trials. The proportion of patients with 3-month dependency (mRS 3–5) has remained at 31% in 2021, while a decrease was observed in other countries. Lower IVT rate and delays in DTP time for EVT could be attributable to this finding, at least partly.

CONCLUSION

These findings from the CRCS-K-NIH registry underscore unique epidemiological and clinical features of stroke in Korea, including a relatively younger stroke onset considering Korea's life expectancy, higher diabetes and smoking prevalence, but lower AF prevalence. Notably, the lower rate of IVT and prolonged DTP times for EVT are pressing concerns requiring immediate intervention. Although dual antiplatelet therapy for non-CE stroke and DOACs for AF-related stroke have been effectively adopted, the declining use of warfarin and increasing use of DOACs for non-AF CE stroke warrants draw our attention. Prompt action to address these challenges is crucial.

SUPPLEMENTARY MATERIALS

Supplementary Table 1
Database structure of the CRCS-K-NIH registry

Supplementary Table 2
Comparison of baseline characteristics of acute ischemic stroke patients between the CRCS-K database and national audit data from Acute Stroke Quality Assessment Program from Health Insurance Review and Assessment Service of 2018

Supplementary Table 3
Cumulative number of registered acute stroke patients according to participating centers

Supplementary Table 4
Number of acute ischemic stroke cases according to age strata in 2021

Supplementary Table 5
Demographic change in patients with acute ischemic stroke between 2008 and 2021

Supplementary Table 6
The prevalence of hypertension, diabetes, hypercholesterolemia and current smoking among general population according to countries

Supplementary Table 7
Major vascular risk factors and pre-stroke management between 2008 and 2021

Supplementary Table 8
Secular trends of TOAST Classification

Supplementary Table 9
Proportion of patients with intracranial, extracranial steno-occlusion or without steno-occlusion

Supplementary Table 10
Potential cardioembolic sources between 2008 and 2021

Supplementary Table 11
Distribution of pre-stroke mRS score

Supplementary Table 12
History of vascular events

Supplementary Table 13
Premorbid mRS according to previous history of stroke

Supplementary Table 14
Profiles of recanalization therapies for ischemic strokes

Supplementary Table 15
The median DTN and DTP time and the proportion of patients with DTN time within 60 minutes and DTP time within 90 minutes between 2008 and 2021

Supplementary Table 16
Parameters of recanalization therapy across the participating centers in 2021

Supplementary Table 17
Onset to hospital arrival time in 2008–2020 and 2021

Supplementary Table 18
Stroke unit/ICU care during acute period

Supplementary Table 19
Performance of brain imaging (2008–2021)

Supplementary Table 20
Profile of laboratory tests between 2008 and 2021

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Supplementary Table 21
Performance of cardiologic workups (2008–2021)

Supplementary Table 22
Acute (within 48 hours of hospitalization) antithrombotic medications between 2008 and 2021 (multiple choices permitted)

Supplementary Table 23
Antithrombotic medications at discharge between 2008 and 2021 (multiple choices permitted)

Supplementary Table 24
Use of aspirin plus clopidogrel at discharge in minor and non-minor stroke patients between 2008 and 2021

Supplementary Table 25
The prescription of statin at discharge

Supplementary Table 26
Surgical interventions during acute period of stroke (2008 and 2021)

Supplementary Table 27
Cumulative incidences (%) of vascular events at 1 year after stroke according to the TOAST classification

Supplementary Fig. 1
Monthly query volumes of the CRCS-K registry from 2018 to 2021.

Supplementary Fig. 2
Cumulative number of acute stroke patients since April 2008.

Supplementary Fig. 3
The average age of stroke onset among countries.

Supplementary Fig. 4
Proportion of TOAST classification between 2008 and 2021.

Supplementary Fig. 5
Center disparities in door-to-needle time (**A**), and door-to-puncture time (**B**) in 2021.

Supplementary Fig. 6
The prescription of statin at discharge among LAA, SVO, CE subtypes and all patients.

Supplementary Fig. 7
Proportions of mRS score at 3 months after stroke.

Supplementary Fig. 8
Proportions of mRS score at 1 year after stroke.

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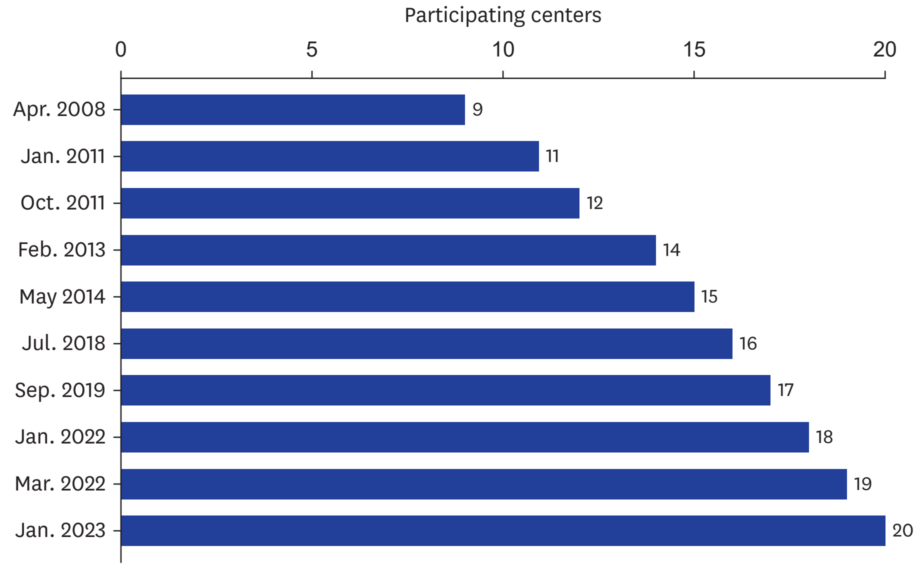
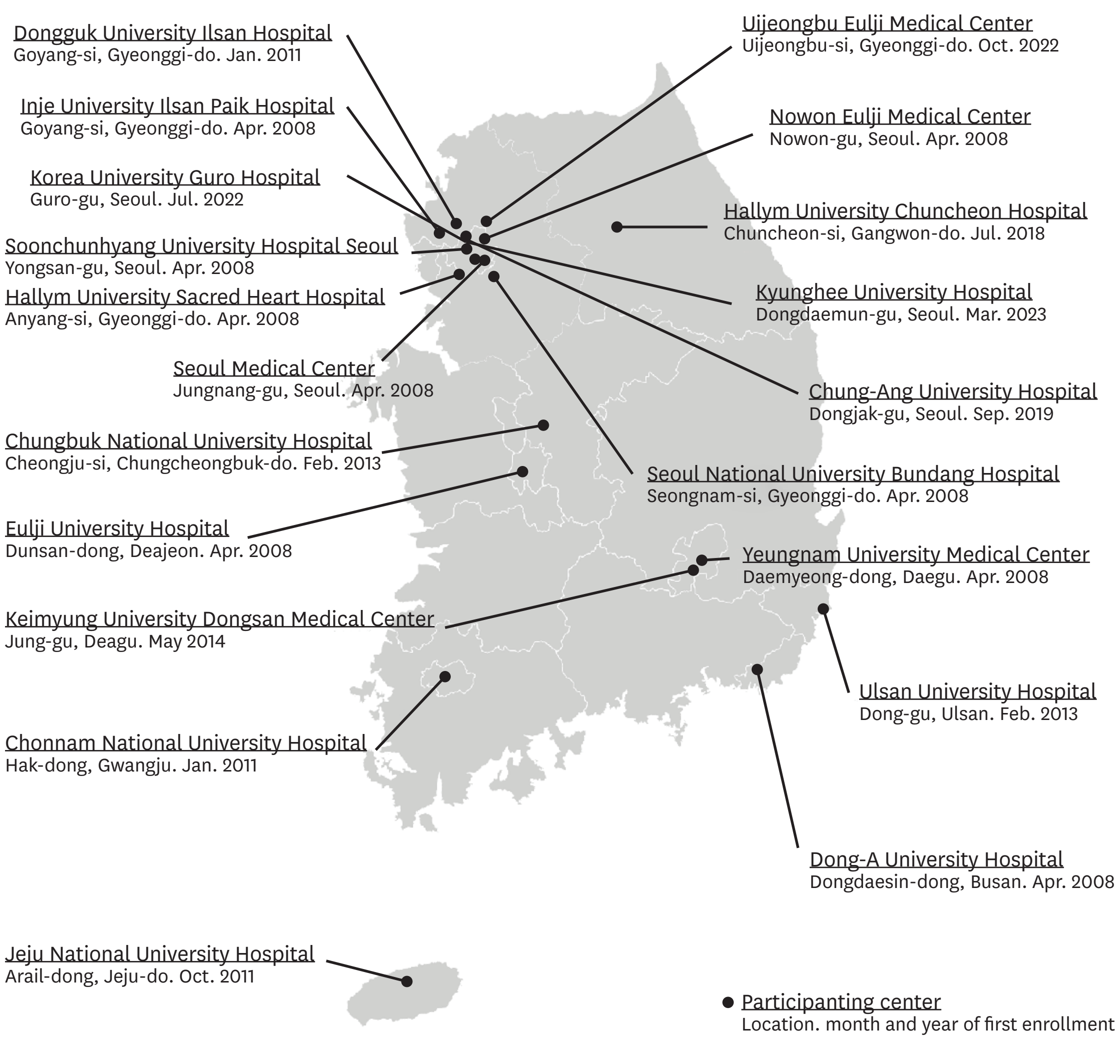
Appendix 1. Glossary "History of the CRCS-K-NIH registry"





The Clinical Research Center for Stroke (CRCS), under the leadership of director Byung-Woo Yoon from Seoul National University Hospital, was founded in 2006. Its creation aimed to enhance multicenter clinical research and develop clinical practice guidelines, supported financially by the Korean Government (HI10C2020). The CRCS encompassed six divisions, among which the Clinical Research Collaboration for Stroke in Korea (CRCS-K), led by principal investigator Hee-Joon Bae from Seoul National University Bundang Hospital, focused on epidemiological studies. Since its initiation, CRCS-K has involved stroke physicians from both academic and regional centers in building a comprehensive multicenter cohort for acute stroke patients.

In April 2008, nine centers, including Eulji General Hospital, Eulji University Hospital, Dong-A University Hospital, Seoul National University Bundang Hospital, Seoul Medical Center, Soonchunhyang University Hospital Seoul, Yeungnam University Medical Center, Inje University Ilsan Paik Hospital, and Hallym University Sacred Heart Hospital, launched a prospective registry for consecutive acute stroke patients. This registry utilized a web-based database system available at http://www.stroke-crc.or.kr/ecrf/. The primary goal of CRCS-K at this stage was to enhance the quality of stroke care at the participating centers and to develop and disseminate the e-QI system across Korean hospitals. Data managers from CRCS-K are responsible for collecting and auditing all data registered by each center. In November 2009, five centers began the prospective collection of stroke outcomes, including modified Rankin Scale (mRS) scores, at 3 months and 1 year post-stroke.

In January 2011, Dongguk University Ilsan Hospital and Chonnam National University Hospital joined CRCS-K, broadening its geographic scope to include South Korea's southwestern region. That year marked the initiation of a prospective outcome capture system by all participating centers, extending data collection to include early neurological deterioration (END), clinical events such as stroke recurrence, death, and other vascular events up to 1 year post-stroke, along with medication adherence based on patient self-reporting.

Jeju National University Hospital, situated on Korea's southernmost island, became part of CRCS-K in October 2011. The network continued to expand with Ulsan University Hospital and Chungbuk National University Hospital joining in February 2013, Keimyung University Dongsan Medical Center in May 2014, Hallym University Chuncheon Sacred Heart Hospital in July 2018, Chungang University Hospital in September 2019, Euijeongbu Eulji University Hospital in January 2022, Korea University Guro Hospital in March 2022, and Kyunghee University Hospital in January 2023. As of now, CRCS-K comprises 20 member sites across the Republic of Korea. This report includes data up to 2021 from 17 centers.

1. Operational definition of vascular risk factors: Hypertension was identified as a mean systolic blood pressure of 140 mmHg or more, or a mean diastolic blood pressure of 90 mmHg or more, measured repeatedly after the acute stage of stroke. It could also be defined by the use of antihypertensive medication, or a self-reported physician diagnosis. Diabetes was characterized by a fasting blood glucose level of 126 mg/dL or higher, a non-fasting glucose level of 200 mg/dL or higher, a glycated hemoglobin A1C (HbA1c) level of 6.5% or higher, the use of hypoglycemic agents, diabetic medication at discharge, or a self-reported physician diagnosis. Dyslipidemia was defined by a serum total cholesterol level exceeding 240 mg/dL, a low-density lipoprotein cholesterol level above 160 mg/dL after fasting for more than 8 hours, a history of statin use, or a self-reported physician diagnosis. Atrial fibrillation was determined by any electrocardiographic evidence of atrial fibrillation during admission or a self-reported physician diagnosis. Current smoking status was defined as someone who had smoked at least one cigarette in the last month.
2. Onset to door time: Symptom onset to emergency room (ER) visit time.
3. Door to imaging time: ER visit to neuroimaging time.
4. Door to Needle time: ER visit to intravenous (IV) tissue plasminogen activator (tPA) time.
5. Onset to Needle time: Symptom onset to IV tPA time.
6. Door to puncture time: ER visit to groin puncture time.
7. Onset to puncture time: Symptom onset to groin puncture time.
8. Onset to reperfusion time: Symptom onset to reperfusion time.
9. Definition of END: END was characterized by either new neurological symptoms or signs, or neurological worsening, meeting one or more of the following criteria: an increase in the total National Institutes of Health Stroke Scale (NIHSS) score by 2 or more, an increase in NIHSS subscores 1a, 1b, or 1c (level of consciousness) by 1 or more, or an increase in NIHSS subscores 5a, 5b, 6a, or 6b (motor) by 1 or more. This has to occur during hospitalization for an index stroke and within 3 weeks from onset. The causes of ENDs are categorized into stroke recurrence, stroke progression, symptomatic hemorrhagic transformation, other causes (such as deep venous thrombosis, pulmonary embolism, myocardial infarction, among others), or unknown etiologies.

   Stroke recurrence during hospitalization was identified as END caused by new distinct lesions on follow-up brain imaging in patients who had been neurologically stable for 24 hours before the new deficit. Stroke progression was determined as END resulting from progressive ischemia, swelling of the infarcted tissue, or perilesional edema, as evidenced on follow-up imaging. Symptomatic hemorrhagic transformation was deemed the cause of END if the neurological decline was due to documented hemorrhagic transformation on brain imaging. Events of END attributed to medical conditions (e.g., aspiration pneumonia) were classified under other causes.
10. Definition of vascular events after stroke: Vascular events following a stroke encompass stroke recurrence, myocardial infarction, vascular death, all-cause mortality and a composite of stroke recurrence, myocardial infarction, and all-cause mortality. Stroke recurrence involves new neurological symptoms or signs attributed to cerebrovascular causes, persisting beyond 24 hours, with physician documentation. This definition encompasses early neurological deterioration identified as stroke progression. Myocardial infarction refers to a new physician-diagnosed acute myocardial infarction prompting a hospital visit. Vascular death includes fatalities resulting from stroke, acute myocardial infarction, or sudden death.