

# Incidence and Post-Stroke Survival in the Normandy Stroke Population-Based Study (2017–2022)

## Impact of Time-Based Versus Tissue-Based Definitions

Ahmad Nehme,<sup>1,2</sup> Romain Schneckenburger,<sup>1,2</sup> Marguerite Watrin,<sup>3</sup> Jean Bouchart,<sup>1,2</sup> Marion Boulanger,<sup>1,2</sup> Julien Cogez,<sup>2</sup> Sophie Guettier,<sup>2</sup> Estelle La Porte,<sup>1,2</sup> Lucie Laroche,<sup>4</sup> Gwendoline Le Du,<sup>3</sup> Olivier Martinaud,<sup>2,5</sup> Rémy Morello,<sup>3</sup> Denis Vivien,<sup>1,6</sup> and Emmanuel Touzé<sup>1,2</sup>

### Correspondence

Prof. Touzé

emmanuel.touze@unicaen.fr

*Neurology*® 2026;107:e218457. doi:10.1212/WNL.00000000000218457

## Abstract

### Objectives

The 11th edition of the International Classification of Diseases (ICD-11) incorporates a tissue-based definition of stroke and may alter estimates of incidence and outcomes. We assessed whether transitioning from a time-based to a tissue-based definition introduces age-dependent changes in stroke incidence and post-stroke survival.

### Methods

The Normandy Stroke Study is a population-based study using multiple overlapping sources to identify stroke cases in Caen-Normandy-Metropole, France. Events occurring between May 15, 2017, and December 31, 2022, were classified using time-based (symptoms  $\geq 24$  hours) and tissue-based definitions (symptoms  $\geq 24$  hours or  $< 24$  hours with neuroimaging evidence of ischemic injury).

### Results

Among 3,826 first-ever strokes meeting the tissue-based definition, median (IQR) age was 76 (64–85) years, and 1,932 (50.5%) were female. The age-standardized incidence rate of stroke (95% CI) was 161 (156–166) per 100,000 person-years (ESP2013), including 132 (128–137) for ischemic or undetermined stroke, 22 (20–24) for intracerebral hemorrhage, and 7 (6–8) for subarachnoid hemorrhage. Three-year mortality was 36.4% (95% CI 34.9–38.0). Compared with the time-based definition, the tissue-based definition increased stroke incidence by 6.5% and reduced 3-year mortality by 3.9%. The impact of the tissue-based definition on stroke incidence was greater at younger ages (all strokes: younger than 55 years = +8.5%; 55 years or older = +6.0%; ischemic stroke: younger than 55 years = +12.5%; 55 years or older = +7.3%).

### Discussion

Adoption of a tissue-based definition modestly increased stroke incidence and post-stroke survival, with greater impacts at younger ages. Implementation of ICD-11 may introduce age-related differences in temporal trends, highlighting the importance of consistent definitions in stroke surveillance.

## Introduction

Measuring the burden of stroke is essential for planning stroke services and prevention strategies.<sup>1</sup> Introduced in 2022, the World Health Organisation's 11th edition of the International Classification of Diseases (ICD-11) may alter estimates of stroke incidence and outcomes because it newly classifies patients with symptoms lasting  $< 24$  hours and neuroimaging findings of acute infarction as having had a stroke.

<sup>1</sup>Université Caen Normandie - UNICAEN, INSERM, PhIND (Physiopathology and Imaging of Neurological Disorders), Institut BBM@C (Brain, Blood and Memory @ Caen Normandie), Cyceron, Caen, France; <sup>2</sup>Centre Hospitalier Universitaire de Caen Normandie, Service de Neurologie, Caen, France; <sup>3</sup>Centre Hospitalier Universitaire de Caen Normandie, Service de Biostatistique et Recherche Clinique, Caen, France; <sup>4</sup>Centre de Traitement des Données du Cancéropôle Nord-Ouest, Centre François Baclesse, Caen, France; <sup>5</sup>Université Caen Normandie - INSERM, U1077, EPHE, Neuropsychologie et Imagerie de la Mémoire Humaine, Caen, France; and <sup>6</sup>Centre Hospitalier Universitaire de Caen Normandie, Département de Recherche Clinique, Caen, France.

MORE ONLINE

Supplementary Material

This population-based study aimed to provide contemporary estimates of stroke incidence, 28-day fatality, and 3-year survival and to determine how these vary between tissue-based and time-based stroke definitions overall and across age groups.

## Methods

### Standard Protocol Approvals, Registrations, and Patient Consents

The Normandy Stroke Study (NSS) was approved by an ethics committee (Comité de Protection des Personnes, 009/2017).<sup>2</sup> Nonopposition was sought in accordance with French legislation regarding observational studies, but written informed consent was not required.

### Study Setting, Definitions, and Outcomes

The study population comprised permanent residents aged 30 days or older living in the Caen-Normandie-Metropole area at the time of stroke (eTable 1, eFigure 1). Cases were identified using overlapping prospective and retrospective sources (eMethods, eTable 2). This analysis included participants with a first-ever stroke occurring between May 15, 2017, and December 31, 2022.

Under the tissue-based definition, ischemic stroke (IS) was defined as neurologic dysfunction caused by focal cerebral, retinal, or spinal infarction, with symptoms lasting  $\geq 24$  hours or until death, or lasting  $< 24$  hours with pathologic or imaging evidence of ischemic injury in a defined vascular territory.<sup>3</sup> Under the time-based definition, IS was defined as neurologic dysfunction caused by focal cerebral, retinal, or spinal infarction, with symptoms lasting  $\geq 24$  hours or until death.

Events occurring before or during the study were reviewed and classified according to both definitions. In all analyses, a study event was classified as a first-ever stroke when the patient had no event meeting the tissue-based definition before study entry. Statistical methods are reported in the eMethods.

## Results

### Demographics and Stroke Subtypes

Over 2,317,007 person-years of observation, 4,244 first-in-study events met the tissue-based stroke definition, of which 3,826 (90.2%) were first-ever strokes. Median (IQR) age was 76 (64–85) years, and 1,932 (50.5%) patients were female. Ascertainment sources and management settings are reported in eTable 3.

Cerebral infarction lasting  $> 24$  hours was the most common stroke subtype ( $n = 2,805$ , 73.3%; median age 77 years), followed by intracerebral hemorrhage (ICH,  $n = 511$ , 13.4%; 77 years), cerebral infarction lasting  $< 24$  hours ( $n = 246$ , 6.4%; 72 years), subarachnoid hemorrhage (SAH,  $n = 151$ ,

4.0%; 58 years), retinal infarction ( $n = 83$ , 2.2%; 72 years), undetermined stroke ( $n = 20$ , 0.5%; 87 years), and spinal cord infarction ( $n = 10$ , 0.3%; 66 years). Among patients with cerebral infarction or undetermined stroke, 2,692 (87.7%) underwent a brain MRI at a median (IQR) of 1 (0–3) day from symptom onset. The median (IQR) NIHSS was 4 (1–10), including 4 (2–9) for cerebral infarction lasting  $> 24$  hours and 12 (4–22.75) for ICH.

### Incidence (Tissue-Based Definition)

The age-standardized incidence rate (ASIR) of stroke was 161 (95% CI 156–166) per 100,000 person-years (ESP 2013), including 132 (128–137) for ischemic or undetermined stroke, 22 (20–24) for ICH, and 7 (6–8) for SAH (Table 1, eTable 4).

Stroke incidence was higher in male patients than in female patients (IRR = 1.48; 95% CI 1.39–1.58), with a similar pattern for IS (IRR = 1.55; 95% CI 1.44–1.66) and ICH (IRR = 1.35; 95% CI 1.13–1.61), but not SAH (IRR = 0.76; 95% CI 0.55–1.06). Above age 35 years, incidence rates were higher in male patients (stroke: IRR = 1.50; 95% CI 1.41–1.60; IS: IRR = 1.57; 95% CI 1.46–1.69; ICH: IRR = 1.37, 95% CI 1.14–1.64) (eFigure 2). In contrast, stroke incidence was higher in female patients younger than age 35 years (IRR = 1.36; 95% CI 0.89–2.10), driven by SAH (IRR = 2.04, 95% CI 0.54–9.66) and IS (IRR = 1.45; 95% CI 0.85–2.53).

### 28-Day Fatality and 3-Year Mortality (Tissue-Based Definition)

Twenty-eight-day fatality occurred in 540 patients (14.1%; 95% CI 13.0–15.3) (eTable 5) and was 9.7% (8.7–10.8) for IS, 37.0% (32.8–41.3) for ICH, and 28.5% (21.4–36.4) for SAH. No patient with cerebral infarction lasting  $< 24$  hours died within 28 days.

Three-year mortality occurred in 1,393 patients (36.4%; 95% CI 34.9–38.0) (eTable 5, eFigure 3) and was 33.2% (31.6–34.9) for IS, 56.4% (51.9–60.7) for ICH, and 35.1% (27.5–43.3) for SAH. Patients with cerebral infarction lasting  $< 24$  hours had lower 3-year mortality (14.6%, 95% CI 10.5–19.7) compared with the other patients with IS or undetermined stroke (34.8%, 95% CI 33.1–36.6).

### Time-Based vs Tissue-Based Stroke Definition

A total of 3,599 first-ever strokes met the time-based definition, corresponding to an ASIR of 151 (95% CI 146–156) per 100,000 person-years (ESP2013) (eTables 6–8).

Compared with the time-based definition, the tissue-based definition increased the ASIR by 6.5%, with a larger relative increase in patients younger than 55 years (8.5%) than 55 years or older (6.0%) (Figure 1). The increase in the ASIR of IS was 8.1% and was again greater at younger ages (younger than 55 years: 12.5%; 55 years or older: 7.3%). Among patients in the NSS with stroke or TIA lasting  $< 24$  hours,

**Table 1** Incidence Rate of First-Ever Stroke in the Normandy Stroke Study (2017–2022, Tissue-Based Stroke Definition)

| Age (y)         | All      |              |                         | Male patients |              |                         | Female patients |              |                         |
|-----------------|----------|--------------|-------------------------|---------------|--------------|-------------------------|-----------------|--------------|-------------------------|
|                 | N events | Person-years | Incidence rate (95% CI) | N events      | Person-years | Incidence rate (95% CI) | N events        | Person-years | Incidence rate (95% CI) |
| Younger than 20 | 20       | 562,152      | 4 (2–5)                 | 11            | 287,421      | 4 (2–7)                 | 9               | 274,731      | 3 (1–6)                 |
| 20–24           | 11       | 169,726      | 6 (3–12)                | 6             | 84,275       | 7 (3–15)                | 5               | 85,451       | 6 (2–14)                |
| 25–29           | 24       | 135,407      | 18 (11–26)              | 8             | 67,239       | 12 (5–23)               | 16              | 68,168       | 23 (13–38)              |
| 30–34           | 30       | 136,118      | 22 (15–31)              | 11            | 67,439       | 16 (8–29)               | 19              | 68,679       | 28 (17–43)              |
| 35–39           | 39       | 140,694      | 28 (20–38)              | 20            | 69,046       | 29 (18–45)              | 19              | 71,648       | 27 (16–41)              |
| 40–44           | 71       | 140,164      | 51 (40–64)              | 36            | 69,500       | 52 (36–72)              | 35              | 70,664       | 50 (34–69)              |
| 45–49           | 106      | 146,281      | 72 (59–88)              | 62            | 71,982       | 86 (66–110)             | 44              | 74,299       | 59 (43–79)              |
| 50–54           | 134      | 141,976      | 94 (79–112)             | 79            | 68,445       | 115 (91–144)            | 55              | 73,531       | 75 (56–97)              |
| 55–59           | 223      | 142,064      | 157 (137–179)           | 161           | 67,449       | 239 (203–279)           | 62              | 74,615       | 83 (64–107)             |
| 60–64           | 327      | 143,169      | 228 (204–255)           | 214           | 66,835       | 320 (279–366)           | 113             | 76,334       | 148 (122–178)           |
| 65–69           | 388      | 137,891      | 281 (254–311)           | 246           | 63,466       | 388 (341–439)           | 142             | 74,425       | 191 (161–225)           |
| 70–74           | 444      | 110,555      | 402 (365–441)           | 282           | 49,713       | 567 (503–637)           | 162             | 60,842       | 266 (227–311)           |
| 75–79           | 457      | 76,550       | 597 (544–654)           | 233           | 32,635       | 714 (625–812)           | 224             | 43,915       | 510 (445–581)           |
| 80–84           | 525      | 61,542       | 853 (782–929)           | 222           | 23,395       | 949 (828–1,082)         | 303             | 38,147       | 794 (707–889)           |
| 85–89           | 537      | 44,091       | 1,218 (1,117–1,325)     | 185           | 14,484       | 1,277 (1,100–1,475)     | 352             | 29,607       | 1,189 (1,068–1,320)     |
| 90–94           | 353      | 21,842       | 1,616 (1,452–1,794)     | 96            | 5,503        | 1,745 (1,413–2,130)     | 257             | 16,339       | 1,573 (1,386–1,777)     |
| 95 or older     | 137      | 6,785        | 2,019 (1,695–2,387)     | 22            | 1,253        | 1,756 (1,100–2,657)     | 115             | 5,532        | 2,079 (1,716–2,495)     |
| Total           | 3,826    | 2,317,007    | 165 (160–170)           | 1,894         | 1,110,080    | 171 (163–178)           | 1,932           | 1,206,927    | 160 (153–167)           |
| ASIR (2013 ESP) |          |              | 161 (156–166)           |               |              | 196 (187–205)           |                 |              | 132 (126–138)           |
| ASIR (1976 ESP) |          |              | 100 (97–104)            |               |              | 124 (118–130)           |                 |              | 80 (76–84)              |

Abbreviations: ASIR = age-standardized incidence rate; ESP = European Standard Population.  
Incidence rates per 100,000 person-years.

brain MRI use was slightly higher in younger individuals, with similar times from symptom onset to MRI across age groups (eTable 9).

Conversely, patients meeting the tissue-based definition had lower mortality than those meeting the time-based definition, with a 6.5% lower 28-day fatality and a 3.9% lower 3-year mortality (Table 2, eTable 10). These differences were more pronounced at younger ages (28-day fatality: younger than 55 years: –7.8% vs 55 years or older: –6.2%; 3-year mortality: younger than 55 years: –7.8% vs 55 years or older: –3.6%).

## Discussion

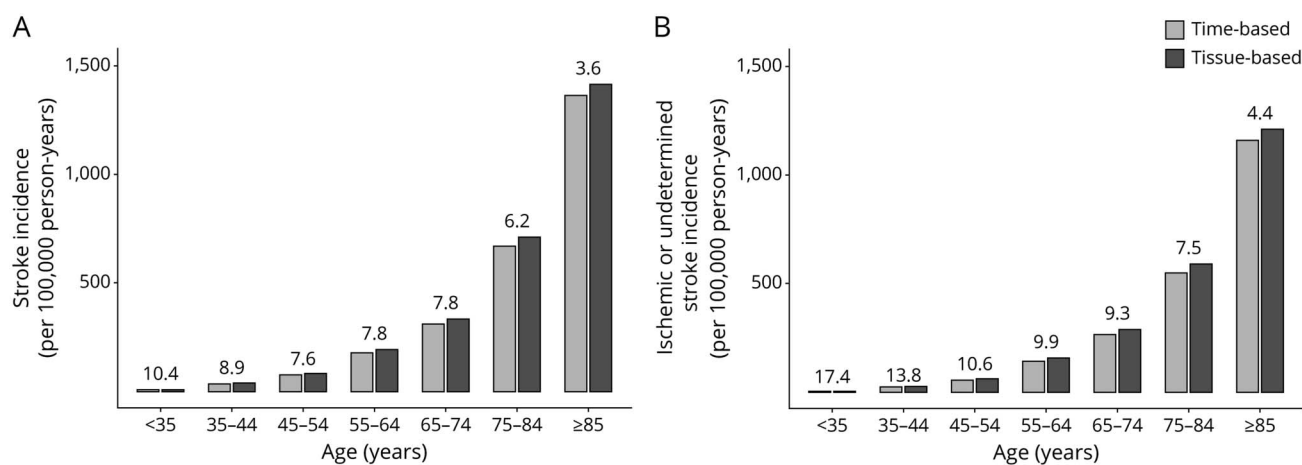
In this population-based study with high MRI use, adopting a tissue-based stroke definition increased incidence by 6.5% and reduced 3-year mortality by 3.9% compared with the traditional time-based definition. These effects were

more pronounced at younger ages, suggesting that the implementation of ICD-11 may bias temporal trends in stroke incidence and post-stroke survival, particularly when comparing age groups over time.

The increase in stroke incidence was similar to findings from South London (6.8%)<sup>4</sup> and Nueces County (4.4%),<sup>5</sup> although lower than that reported in Geneva (15.0%).<sup>6</sup> The larger increase in Geneva was attributed to greater MRI access. However, MRI use in the NSS was similar high, suggesting that the impact of MRI availability on incidence estimates may previously have been overestimated.

The greater increase in incidence among younger individuals may reflect differences in referral pattern and MRI use after transient neurologic symptoms, as well as age-related differences in stroke severity, etiology, and brain frailty, which can influence symptom duration.<sup>4,6,7</sup> These findings highlight the importance of maintaining consistent definitions and

**Figure 1** Age-Stratified Impact of the Tissue-Based Compared With the Time-Based Definition on Stroke Incidence



Relative percentage increase in incidence rate is provided for first-ever stroke (A) and ischemic or undetermined stroke as a first-ever stroke (B). Under the tissue-based definition, ischemic stroke was defined as neurologic dysfunction caused by focal cerebral, retinal, or spinal infarction, with symptoms lasting  $\geq 24$  hours or until death, or lasting  $< 24$  hours with pathologic or imaging evidence of ischemic injury in a defined vascular territory. Under the time-based definition, ischemic stroke was defined as neurologic dysfunction lasting  $\geq 24$  hours or until death.

ascertainment methods in long-term population-based stroke surveillance.

This study has several limitations. First, death certificates and national admission databases were not available for case ascertainment, potentially leading to underestimation of events occurring in the community or outside of the study territory. Second, symptom duration may have been underestimated in

patients not evaluated at our centre, potentially exaggerating the impact of the tissue-based definition on incidence. Third, imaging-negative transient ischemic attacks managed in the community were not systematically evaluated, and some may have been imaging-negative minor strokes.<sup>7</sup> Fourth, the impact of the tissue-based definition may not be generalizable to all settings because it likely depends on local referral patterns and MRI access.

**Table 2** Age-Stratified Impact of the Tissue-Based Compared With the Time-Based Definition on 28-Day Fatality and 3-Year Mortality After Stroke

|                  | N deaths (tissue) | N strokes (tissue) | Outcome (tissue), % | N deaths (time) | N strokes (time) | Outcome (time), % | Relative change with the tissue-based definition, % |
|------------------|-------------------|--------------------|---------------------|-----------------|------------------|-------------------|-----------------------------------------------------|
| 28-day fatality  |                   |                    |                     |                 |                  |                   |                                                     |
| Younger than 55  | 36                | 435                | 8.3                 | 36              | 401              | 9.0               | −7.8                                                |
| 55–64            | 72                | 550                | 13.1                | 73              | 510              | 14.3              | −8.5                                                |
| 65–74            | 72                | 832                | 8.7                 | 73              | 772              | 9.5               | −8.5                                                |
| 75–84            | 111               | 982                | 11.3                | 111             | 925              | 12.0              | −5.8                                                |
| 85 or older      | 249               | 1,027              | 24.2                | 250             | 991              | 25.2              | −3.9                                                |
| All (crude)      | 540               | 3,826              | 14.1                | 543             | 3,599            | 15.1              | −6.5                                                |
| 3-year mortality |                   |                    |                     |                 |                  |                   |                                                     |
| Younger than 55  | 55                | 435                | 12.6                | 55              | 401              | 13.7              | −7.8                                                |
| 55–64            | 119               | 550                | 21.6                | 117             | 510              | 22.9              | −5.7                                                |
| 65–74            | 206               | 832                | 24.8                | 202             | 772              | 26.2              | −5.4                                                |
| 75–84            | 345               | 982                | 35.1                | 335             | 925              | 36.2              | −3.0                                                |
| 85 or older      | 668               | 1,027              | 65.0                | 655             | 991              | 66.1              | −1.6                                                |
| All (crude)      | 1,393             | 3,826              | 36.4                | 1,364           | 3,599            | 37.9              | −3.9                                                |

## Conclusions

In this population-based study, transitioning to a tissue-based definition modestly increased incidence and post-stroke survival, with stronger effects at younger ages. These findings suggest that ICD-11 may introduce age-related bias into temporal trends of stroke incidence and outcomes, underscoring the importance for consistent surveillance methods over time.

## Acknowledgment

We thank the Normandy Stroke team, the Normandy administrative region, the Fondation Matmut Paul Bennetot, the Centre de Traitement des Données du cancérpôle Nord-Ouest, the Association France AVC Normandie, and all participating centers (CHU de Caen-Normandie, Hôpital Privé Saint Martin, Polyclinique du Parc, Fondation hospitalière de la Miséricorde, Centre d'Imagerie Médicale de Basse-Normandie, Centre Régional de Lutte contre le cancer François Baclesse, Centre Hospitalier de Falaise, Centre Hospitalier de Flers, Centre Hospitalier d'Argentan, Centre Hospitalier de Saint Lô, Association SOS Médecins Caen).

## Author Contributions

A. Nehme: drafting/revision of the manuscript for content, including medical writing for content; major role in the acquisition of data; study concept or design; analysis or interpretation of data. R. Schneckenburger: drafting/revision of the manuscript for content, including medical writing for content; major role in the acquisition of data; study concept or design; analysis or interpretation of data. M. Watrin: drafting/revision of the manuscript for content, including medical writing for content; major role in the acquisition of data; study concept or design; analysis or interpretation of data. J. Bouchart: drafting/revision of the manuscript for content, including medical writing for content; major role in the acquisition of data. M. Boulanger: drafting/revision of the manuscript for content, including medical writing for content; major role in the acquisition of data. J. Cogez: drafting/revision of the manuscript for content, including medical writing for content; major role in the acquisition of data. S. Guettier: drafting/revision of the manuscript for content, including medical writing for content; major role in the acquisition of data. E. La Porte: drafting/revision of the manuscript for content, including medical writing for content;

major role in the acquisition of data. L. Laroche: drafting/revision of the manuscript for content, including medical writing for content; major role in the acquisition of data. G. Le Du: drafting/revision of the manuscript for content, including medical writing for content; major role in the acquisition of data; study concept or design; analysis or interpretation of data. O. Martinaud: drafting/revision of the manuscript for content, including medical writing for content; major role in the acquisition of data. R. Morello: drafting/revision of the manuscript for content, including medical writing for content; study concept or design. D. Vivien: drafting/revision of the manuscript for content, including medical writing for content; study concept or design. Emmanuel Touzé: drafting/revision of the manuscript for content, including medical writing for content; major role in the acquisition of data; study concept or design; analysis or interpretation of data.

## Study Funding

The Normandy Stroke Study is funded by the Normandy administrative region and a private foundation (Fondation Matmut Paul Bennetot).

## Disclosure

The authors report no relevant disclosures. Go to [Neurology.org/N](https://www.neurology.org/N) for full disclosures.

## Publication History

Received by *Neurology*® April 24, 2026. Accepted in final form June 15, 2026. Submitted and externally peer reviewed. The handling editor was Editor-in-Chief José Merino, MD, MPhil, FAAN.

## References

1. GBD 2021 Stroke Risk Factor Collaborators. Global, regional, and national burden of stroke and its risk factors, 1990-2021: a systematic analysis for the Global Burden of Disease Study 2021. *Lancet Neurol*. 2024;23(10):973-1003. doi:10.1016/S1474-4422(24)00369-7
2. Schneckenburger R, Boulanger M, Watrin M, Le Du G, Morello R, Touzé E. Incidence and outcomes of acute cerebrovascular events: methodology of the population-based normandy stroke study. *Neuroepidemiology*. 2023;57(2):112-120. doi:10.1159/000525408
3. Sacco RL, Kasner SE, Broderick JP, et al. An updated definition of stroke for the 21st century. *Stroke*. 2013;44(7):2064-2089. doi:10.1161/STR.0b013e318296aeca
4. Pantoja-Ruiz C, Emmett ES, Bhalla A, et al. Impact of ICD-11 stroke definition on incidence and outcomes. *Neurol Open Access*. 2026;2(1):e000051. doi:10.1212/WNL.0000000000000051
5. Morgenstern LB, Zahuranec DB, Lim J, et al. Tissue-based stroke definition impacts stroke incidence but not ethnic differences. *J Stroke Cerebrovasc Dis*. 2021;30(6):105727. doi:10.1016/j.jstrokecerebrovasdis.2021.105727
6. Dirren E, Escibano Paredes JB, Klug J, et al. Stroke incidence, case fatality, and mortality using the WHO International Classification of Diseases 11: the Geneva Stroke Study. *Neurology*. 2025;104(5):e213353. doi:10.1212/WNL.00000000000213353
7. Béjot Y, Mehta Z, Giroud M, Rothwell PM. Impact of completeness of ascertainment of minor stroke on stroke incidence: implications for ideal study methods. *Stroke*. 2013;44(7):1796-1802. doi:10.1161/strokeaha.113.000949