


## REVIEW PAPER

# The epidemiology of stroke in Africa: A systematic review of existing methods and new approaches

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Accurate epidemiological surveillance of the burden of stroke is direly needed to facilitate the development and evaluation of effective interventions in Africa. The authors therefore conducted a systematic review of the methodology of stroke epidemiological studies conducted in Africa from 1970 to 2017 using gold standard criteria obtained from landmark epidemiological publications. Of 1330 articles extracted, only 50 articles were eligible for review grouped under incidence, prevalence, case-fatality, health-related quality of life, and disability-adjusted life-years studies. Because of various challenges, no study fulfilled the criteria for an excellent stroke incidence study. The relatively few stroke epidemiology studies in Africa have significant methodological flaws. Innovative approaches leveraging available information and communication technology infrastructure are recommended to facilitate rigorous epidemiological studies for accurate stroke surveillance in Africa.

## 1 | INTRODUCTION

Africa bears the greatest burden of hypertension,<sup>1</sup> which is the strongest and most common modifiable risk factor for stroke.<sup>2-4</sup> Consequently, strokes are an increasingly important health determinant especially in Africa, where these events were historically reported to be rare likely as a result of lack of resources to conduct proper community-based studies to assess its burden.<sup>5</sup> Despite the proposition that increased stroke occurrence is linked to gains in longevity on the continent, people of African descent clearly experience strokes at a younger age and have worse outcomes.<sup>6,7</sup> Furthermore, Africa

appears to have the highest incidence, prevalence, and case fatality rates of stroke.<sup>8-12</sup>

However, making unambiguous statements about the trend of the burden of stroke and the impact of any interventions on this trend on the African continent is limited by the quality of epidemiological information from this population.

Stroke surveillance is useful in determining the present and projected burden of the disease and monitoring the impact of interventions.<sup>13</sup> Rigorous stroke epidemiology is prerequisite for the efficient planning and delivery of stroke services, the effective application of current stroke prevention strategies, the development of new strategies, and our understanding of the mechanisms of stroke.<sup>14</sup> The accuracy of a stroke epidemiological study is, however, contingent on

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multiple prerequisites, which include: obtaining an accurate diagnosis of stroke events based on standard definitions and methods in a clearly defined (enumerated) population or sample (also known as the reference population or the denominator).<sup>15</sup> This will also allow comparison of estimates across regions and nations without methodological bias.<sup>16</sup>

Although there are no consensus guidelines, there have been numerous efforts to standardize epidemiological methods for various study designs.<sup>5,16,17</sup> Conforming with these standard methods is required for rigorous and up-to-date epidemiological studies of stroke in Africa. Such studies will provide data and risk estimates that are critical resources for research programs such as Human Heredity and Health in Africa (H3Africa)<sup>17</sup> and the Stroke Investigative Research and Education Network (SIREN) component.<sup>5</sup>

This systematic review was therefore conducted to assess the methodological rigor of existing stroke epidemiological studies conducted in Africa with respect to the recommended standards. We also provide a succinct description of a proposed stroke surveillance study, the ARISES (African Rigorous Innovative Stroke Epidemiological Surveillance) trial, which has been designed to address the identified methodological limitations in this field by incorporating innovative solutions based on emerging technologies.

## 2 | METHODS

### 2.1 | Search strategy and selection criteria

Using the Preferred Reporting Items for Systematic Review and Meta-Analyses guidelines,<sup>18</sup> data for this review were identified by searches of PubMed, Google Scholar, *African Journals Online*, and from the references of relevant articles from the years 1970 to 2017. The search terms were: "methodology," "population-based," "community-based," "community," "health facility-based," "epidemiology," "epidemiological," "incidence," "prevalence," "Africa," "survey," "surveillance," "fatality," "case-fatality," "stroke," "ischemic stroke," "intracerebral," "intraparenchymal," "subarachnoid," "hemorrhage," "health-related quality of life," and "disability-adjusted life-years." The data were collected and synthesized by the first two authors independently. Only publications in the English language were reviewed. These were later harmonized and emphasis was on articles with full publication for critical review of their methodologies. The criteria for selection included: (1) primarily an epidemiological study in Africa, and (2) full text available.

### 2.2 | Data extraction, synthesis, and critical appraisal

A total of 1328 articles were retrieved from the aforementioned online databases. An additional two studies were identified through other sources by manual search. These articles were independently reviewed by two authors. After the removal of duplicates and articles that were not truly epidemiological studies, 112 articles were left. Of these, the 61 that were not full-text articles and mostly from non-African countries were excluded. The only article not written in

English was also excluded. Fifty articles were therefore retained for review (Figure 1). This review emphasized the methods of these studies and each article was critically appraised under the following headings: study period, recruitment process, case definition and ascertainment, confirmation by computed tomography (CT) or magnetic resonance imaging (MRI), classification as first-ever or recurrent stroke, classification of ischemic stroke subtypes, and denominator population.<sup>16,19</sup> This approach methodically and practically answers all the questions needed for the critical appraisal of epidemiological studies.<sup>20</sup>

### 2.3 | Gold standard methods for assessing stroke epidemiology studies

The standards for stroke incidence studies are summarized in Table 1. In addition, there should be complete population-based case ascertainment, based on multiple overlapping sources of information from hospitals, outpatient clinics, and death certificates.<sup>16,21</sup> Follow-up of patients' vital status for at least 1 month with a reliable method for estimating denominator (census data not more than 5 years old) are essential requirements.<sup>16,21</sup>

Suggested criteria for stroke prevalence studies are included in Table 2.<sup>19</sup> Studies on health-related quality of life also need accurate case ascertainment,<sup>22</sup> including the use of World Health Organization (WHO) definitions for stroke. Additionally, stroke and stroke type should be confirmed by neuroimaging, while health-related quality of life should be measured using a stroke-specific health-related quality of life questionnaire.<sup>23,24</sup> There may not be any specific standards for the study of stroke disability-adjusted life-years—its accurate determination is dependent on the quality of the prevalence and incidence studies from which it is calculated.<sup>25</sup>

## 3 | RESULTS

The studies (n = 50) were regionally grouped into Eastern, Northern, Southern, and Western Africa. Nigeria, from Western Africa had 22 epidemiological studies followed by Egypt from Northern Africa with seven studies. There were 12 studies on incidence, 13 studies on prevalence, 13 studies on case fatality, and 10 studies on health-related quality of life. The only two studies on disability-adjusted life-years were from South Africa (Tables 1–3 and S1, S2).

Three incidence studies were determined at the health institution level, while only one was determined both at the health institution and community levels. Two of the prevalence studies from Nigeria were health institution based and the case definition for these studies was not stated. All but two studies conducted in the Niger Delta region of Nigeria were only in the urban settings. Thirty studies (60%) based their case definitions on the recommended WHO definition of stroke (Tables 1–3 and S1).

Only 16 studies (32%) classified stroke as first-ever or recurrent. These were predominantly incidence studies (Tables 1, 3, and S1). Thirty-four studies (68%) ascertained the diagnosis of stroke with CT or MRI, 11 (32.3%) of which had more than 80% of their patients

**TABLE 1** Stroke incidence studies in Africa

Country, Location, Setting	Author, y	Study period	Recruitment	Case definition	Confirmation by CT or MRI	Classification: first or recurrent	Classification of ischemic stroke	Denominator population
Gold standard/recommendations	Feigin, <sup>16</sup> 2004, Sudlow, <sup>21</sup> 1996, and Vandembroucke, <sup>68</sup> 2013	At least 3 y	Population or community based, prospective, hot pursuit	WHO definition/criteria	>80%	Yes	Yes	Large, well-defined, and stable population
Eastern Africa								
Tanzania, rural	Walker, <sup>12</sup> 2011	June 15, 2003, until June 15, 2006	Community and health institution based	WHO definition	<80%	Yes	No	Yes
Tanzania, rural and urban	Walker, <sup>8</sup> 2010	June 15, 2003, until June 15, 2006	Community and health institution based	WHO definition	<80%	Yes	No	Yes
Northern Africa								
Egypt, Qena, mixed	Khedr, <sup>10</sup> 2014	September 1, 2011, to August 31, 2013	Door-to-door, community based	Not stated	>80%	Yes	No	Yes
Egypt, Al-Kharga, mixed	Farghaly, <sup>39</sup> 2013	June 1, 2005, to May 31, 2008	Door-to-door survey, in three phases	WHO criteria	<80%	No	Yes	Yes
Egypt, Al Quseir, urban	El-Tallawy, <sup>42</sup> 2013	July 1, 2009, to January 31, 2012	Door-to-door survey	WHO criteria	>80%	No	No	Yes
Libya, Benghazi, urban	Ashok, <sup>27</sup> 1986	November 1, 1983, and October 31, 1984	Health institution based	US National Survey of Stroke	>80%	No	Yes	Yes
Southern Africa								
South Africa, Atteridgeville, and Mamelodi suburban areas of Pretoria, urban	Rosman, <sup>29</sup> 1986	May 1, 1984, through April 30, 1985	Health institution based	Harvard Cooperative Stroke Registry	<80%	No	Yes	Yes
South Africa, Agincourt subdistrict, rural	Maredza, <sup>71</sup> 2000	2007–2011	Population based	Not stated	No	No	No	Yes
Mozambique	Damasceno, <sup>44</sup> 2011	August 1, 2005, to July 31, 2006	Health institution based	WHO definition	>80%	Yes	No	Yes (Maputo City population aged 25 years according to the 2007 Census)

(continues)

TABLE 1 (Continued)

Country, Location, Setting	Author, y	Study period	Recruitment	Case definition	Confirmation by CT or MRI	Classification: first or recurrent	Classification of ischemic stroke	Denominator population
Gold standard/recommendations	Feigin, <sup>16</sup> 2004, Sudlow, <sup>21</sup> 1996, and Vandenbroucke, <sup>68</sup> 2013	At least 3 y	Population or community based, prospective, hot pursuit	WHO definition/criteria	>80%	Yes	Yes	Large, well-defined, and stable population
Western Africa								
Nigeria, Ibadan, urban	Osuntokun, <sup>38</sup> 1979	April 1, 1973, to March 30, 1975	Health institution based	Not stated	No	Yes	Yes	Yes (projection of the 1963 Census)
Nigeria, Lagos, urban	Danesi, <sup>43</sup> 2013	Between January 1 and December 31, 2007	Health institution based	WHO definition	<80%	Yes	No	Yes
Nigeria, Akure, urban	Okon, <sup>72</sup> 2015	Between November 1, 2010, and October 31, 2011	Both healthcare and population based	Not stated	>80%	Yes	Yes	Yes

Abbreviations: CT, computed tomography; MRI, magnetic resonance imaging; WHO, World Health Organization. See supporting information for references 42, 43, 44, 68, 71, and 72.

diagnosed with CT or MRI. Only nine studies (18%) further classified ischemic stroke using neuroimaging (Tables 1–3 and S1). Three incidence studies were conducted in less than 3 years (Table 2). Three studies did not state the denominator population for calculating the indices. Two of them only gave the population census from which the denominators were derived.

Only six of the studies on health-related quality of life in patients with stroke used a stroke-specific quality-of-life instrument (Table S1). None of the studies were community based and only four used the WHO definition criteria to select their patients. No study classified ischemic stroke.

In summary, the only study that fulfilled the gold standard criteria for stroke epidemiological study was the prevalence study performed in urban Egypt (Al Qusei) by El-Tallawy and colleagues.<sup>42</sup> Other epidemiological studies on stroke incidence, case fatality, and health-related quality of life were deficient in at least one criterion.

## 4 | DISCUSSION

### 4.1 | Case definition

The WHO definition of stroke<sup>26</sup> with confirmation by CT/MRI scan is one of the suggested criteria for use in stroke epidemiological studies.<sup>19</sup> In their study on the incidence study in Benghazi, Libya, Ashok and colleagues<sup>27</sup> based their diagnosis and categorization of stroke type on an algorithm from the US National Survey of Stroke.<sup>28</sup> However, stroke was confirmed by neuroimaging in over 80% of the clinically diagnosed cases. In addition, Rosman and colleagues<sup>29</sup> adopted the criteria used in the Harvard Cooperative Stroke Registry<sup>30</sup> in their study on the epidemiology of stroke in an urban black population in South Africa. This involved the combination of clinical and laboratory parameters for large artery thrombosis, lacunar infarct, intracerebral hemorrhage, and subarachnoid hemorrhage. Khedr and colleagues<sup>10</sup> did not state the case definition in their study on the prevalence of ischemic and hemorrhagic strokes in Qena Governorate, Egypt.

### 4.2 | Epidemiological study design and location

In the Libyan and South African studies, incidence rate was determined only at the level of health institutions. In epidemiological studies, this would result in underreporting, as many patients with stroke do not present to health institutions.<sup>31</sup> Conversely, in Tanzania, the incidence rate was determined prospectively at both the community level and health facilities with “hot pursuit.”<sup>16</sup> This has been found to be more accurate and reliable compared with retrospective studies.<sup>21</sup>

Typically, prevalence studies should be performed with a door-to-door survey in both the rural and urban communities.<sup>13</sup> However, sometimes prevalence is estimated from cohort studies or by indirect calculation from incidence studies where cases have been followed up at regular intervals over time to determine fatality.<sup>32,33</sup> Most of the studies performed in Nigeria were in the urban settings, which might not provide the full picture.

**TABLE 2** Prevalence studies

Country, Location, Setting	First author, y	Recruitment	Case definition	Clarification by CT or MRI	Denominator population
<b>Gold standard/ recommendation</b>	Feigin, <sup>19</sup> 2003 and Vandenbroucke, <sup>68</sup> 2013	<b>Community door-to-door based</b>	<b>WHO definition/ criteria</b>	<b>Yes (&gt;80%)</b>	<b>Well-defined and stable population</b>
Eastern Africa					
Tanzania, rural	Walker, <sup>73</sup> 2000	Community and health institution based	WHO definition	No	Yes
Northern Africa					
Egypt, Qena, mixed	Khedr, <sup>10</sup> 2014	Door-to-door, community based	Not stated	>80%	Yes
Egypt, Al-Kharga, mixed	Farghaly, <sup>39</sup> 2013	Door-to-door survey, in three phases	WHO criteria	<80%	Yes
Egypt, Al Quseir, urban	El-Tallawy, <sup>42</sup> 2013	Door-to-door survey	WHO criteria	>80%	Yes
Egypt, Assiut, urban	Khedr, <sup>60</sup> 2013	Three-phase door-to-door community-based study	WHO criteria	<80%	Yes
Morocco, Casablanca and Rabat, mixed	Engels, <sup>74</sup> 2014	Two-phase door-to-door community-based survey	WHO criteria	Yes but percentage not stated	Yes
Western Africa					
Nigeria, Lagos, urban	Danesi, <sup>36</sup> 2007	Community based	WHO definition	No	Yes
Nigeria, middle belt region semiurban	Sanya, <sup>37</sup> 2015	Community based	WHO criteria	No	Yes
Nigeria, multicenter study in urban centers	Madu, <sup>75</sup> 2014	Health institution based	Not stated	No	Yes
Nigeria, Zaria, urban	Danjuma, <sup>76</sup> 2005	Health institution based	Not stated	No	No
Nigeria, Niger-Delta/Ebubu and Usokun, rural	Ezejimofor, <sup>9</sup> 2017	Door-to-door, community based	WHO criteria	No	Yes
Nigeria, Niger Delta/ Kegbara-Dere, rural	Onwuchekwa, <sup>77</sup> 2014	Door-to-door, community based	WHO criteria	No	Yes
Benin, Cotonou, urban	Cossi, <sup>78</sup> 2012	Door-to-door community-based survey in three phases	WHO criteria	<80%	Yes

Abbreviations: CT, computed tomography; MRI, magnetic resonance imaging; WHO, World Health Organization. See supporting information for references 68, 42, 60, 73–78.

The only identified study on stroke mortality, conducted in Yaoundé, Cameroon,<sup>34</sup> was not population based. The studies conducted on health-related quality of life and disability-adjusted life-years were all hospital based and may not give an accurate indication of burden of stroke at the population level.

### 4.3 | Confirmation by CT or MRI and further classification of ischemic stroke

A recommendation for an “ideal” high-quality population-based stroke epidemiological study is that at least 80% of the recruited cases should have brain CT/MRI performed.<sup>16</sup> This is for case ascertainment, pathologic classification, and phenotyping of ischemic and hemorrhagic strokes.<sup>35</sup> The stroke incidence studies in rural Tanzania,<sup>12</sup> Lagos, Nigeria,<sup>36</sup> the middle belt region of Nigeria,<sup>37</sup> and one incidence study from Ibadan, Nigeria,<sup>38</sup> did not confirm cases of stroke by CT or MRI. During the time of conduct of the Ibadan stroke registry,

CT technology was not available. This might be the reason these cases were not ascertained and not further classified. Even in Northern Africa, where neuroimaging was performed, only the incidence studies from Egypt, Al-Kharga,<sup>39</sup> and Libya, Benghazi,<sup>27</sup> had further classification of ischemic stroke. Unlike the study by Owolabi,<sup>23</sup> Akinpelu<sup>40</sup> and Vincent-Onabajo<sup>41</sup> and colleagues did not confirm stroke with neuroimaging in their studies on health-related quality of life.

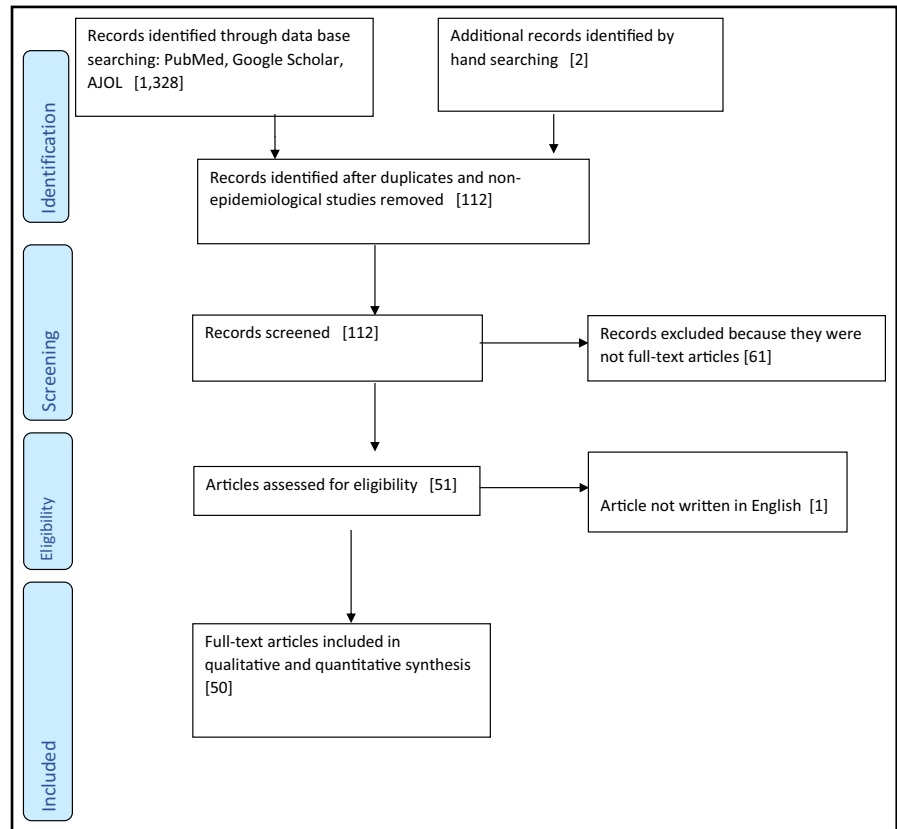
### 4.4 | Classification as first-ever or recurrent stroke

For incidence studies, only the cases of first stroke should be reported and separated from recurrent strokes.<sup>16</sup> Stroke incidence rate would be overestimated if patients with recurrent strokes within the period of surveillance are recruited. It was not clear why this essential criterion was not applied during the course of the four incidence studies.<sup>27,29,39,42</sup> A potential explanation is the possibility of recall bias. Therefore, studies that would indirectly calculate disability-adjusted

TABLE 3 Case-fatality studies

Country, Location, Setting	First author, y	Study period	Recruitment	Case definition	Classification by CT or MRI	Classification: first or recurrent	Classification of ischemic stroke
<b>Gold standard/recommendation</b>	Vandenbroucke, <sup>68</sup> 2013 and Lavados, <sup>79</sup> 2005	At least 1 mo	Community based	WHO definition/criteria	>80%	Yes	Yes
<b>Eastern Africa</b>							
Tanzania/rural	Walker, <sup>12</sup> 2011	June 15, 2003, until June 15, 2006	Community and health institution based	WHO definition	<80%	Yes	No
<b>Southern Africa</b>							
South Africa, Atteridgeville, and Mamelodi suburban areas of Pretoria, urban	Rosman, <sup>29</sup> 1986	May 1, 1984, through April 30, 1985	Health institution based	Harvard Cooperative Stroke Registry	<80%	No	Yes
South Africa, Johannesburg, urban	Mudzi, <sup>80</sup> 2012	Between 2006 and 2010 and followed up for 12 mo	Health institution based	Not stated	>80%	No	Yes
South Africa, Cape Town, urban	de Villiers, <sup>81</sup> 2011	Between August 24, 2004, and January 12, 2006	Health institution based	WHO definition	<80%	No	No
<b>West Africa</b>							
Nigeria, Lagos, urban	Danesi, <sup>43</sup> 2013	Between January 1 and December 31, 2007	Health institution based	WHO definition	<80%	Yes	No
Gambia, Banjul, urban	Garbusinski, <sup>82</sup> 2005	February 2000 to February 2001	Health institution based	WHO criteria	No	No	No
Gambia, Banjul, rural/urban	Walker, <sup>83</sup> 2003	1 y beginning April 1, 1990	Hospital based	WHO definition	No	No	No
Cameroon, Douala, urban	Mapoure, <sup>84</sup> 2014	January 1, 2010, to December 31, 2012	Hospital based	No	>80%	No	No
Nigeria, Jos, urban	Ekeh, <sup>85</sup> 2015	January and December 2006	Hospital based	WHO definition	<80%	No	No
Nigeria, Lagos, urban	Wahab, <sup>86</sup> 2008	February 2003 to May 2004	Hospital based	WHO definition	<80%	Yes	No
Nigeria, Abuja, urban	Alkali, <sup>87</sup> 2013	January 2010 and June 30, 2012	Hospital based	WHO definition	<80%	Yes	Yes
Nigeria, Akure, urban	Okon, <sup>72</sup> 2015	Between November 1, 2010, and October 31, 2011	Both community and health institution based	Not stated	>80%	Yes	Yes
Nigeria, Kano, urban	Femi, <sup>88</sup> 2013	From June 2007 to June 2010	Hospital based	WHO definition	Yes but percentage not stated	No	No

Abbreviations: CT, computed tomography; MRI, magnetic resonance imaging; WHO, World Health Organization. See supporting information for references 43, 68, 72, 79, 80, 81, 82, 83, 84, 85, 86, 87, and 88.



**FIGURE** Preferred Reporting Items for Systematic Reviews and Meta-Analyses flow chart showing the search and selection process for the eligible publications on epidemiological studies of stroke in Africa. AJOL indicates African Journals Online.

life-years from incidence rates without excluding recurrent stroke would give a wrong estimate of the disease burden.

#### 4.5 | Study period and denominator population

The conduct of a prevalence study should be in a population that is large, well-defined, and stable.<sup>19</sup> For incidence studies, data collection should be over a period of several years (continuously or periodically for at least 3 whole calendar years each period) in one and the same catchment area.<sup>16</sup> However, three incidence studies, by Danesi,<sup>43</sup> Damasceno,<sup>44</sup> and Rosman<sup>29</sup> and colleagues were conducted in less than 3 years. This would not be representative of the population being studied. The population census of the area of study is usually used because it has a complete enumeration of the population. The study must also be conducted within 5 years of the census.<sup>19</sup> In this review, an incidence study in Ibadan, Nigeria,<sup>38</sup> was conducted after 5 years of the last census, which rendered the population denominator invalid.

#### 4.6 | Challenges and solutions for rigorous stroke epidemiology in Africa

Common challenges in stroke epidemiological studies include finding stroke events across the myriad of settings where these events occur and where patients seek care, investigating events to determine that strokes meet defined criteria, valid investigations to rule out other causes of symptoms and establish stroke phenotype, accurate

determination of poststroke morbidity and mortality, and accurate counts of the population to establish accurate census and epidemiological indices.

The problem of event reporting is especially important in Africa where knowledge of stroke is limited, significant portions of the populations have limited orthodox health access, and health data reporting is challenging.<sup>45,46</sup> These challenges can be mitigated by establishing a mobile health-driven stroke information system. Such a system can be deployed to improve local stroke literacy and lead to near-total case detection. Following the required community engagements, establishing such an information system could begin with strengthening existing ward health structures and educating the local population about stroke to improve literacy about stroke and cardiovascular events. This information system should use educational materials that have been pretested and documented as culturally sensitive and effective in the communities. Examples include a prevalidated stroke documentary video,<sup>47-49</sup> a stroke dance video,<sup>50</sup> and a pictographic questionnaire for screening stroke in communities.<sup>51,52,45,51,53-56</sup>

Furthermore, an mHealth-driven stroke alert system through which patients with stroke/caregivers/nonorthodox providers can report stroke, and a stroke finding system through which healthcare providers can remotely elicit notifications of stroke cases from all sources can be integrated. Previous research shows mobile phone access approaching 100% in various regions in Africa,<sup>17,49</sup> which makes an mHealth system appropriate in this population. This option will therefore increase ease of reporting cases in surveillance studies.

#### 4.7 | Ethical and infrastructural challenges of conducting accurate stroke surveillance in Africa

Community-based studies, which constitute the best way to determine the true incidence, prevalence, and mortality of stroke, are few and of uneven quality in Africa because of lack of manpower and research funds.<sup>57,61,63,68</sup> Estimating the burden of stroke in the community is complicated by the difficulty in making a retrospective and yet accurate diagnosis of stroke and stroke type.<sup>57,63,64,68</sup> Estimations are also biased by an underrepresentation of fatal cases.<sup>57,63,64,68</sup> However, in Africa, incidence studies, which require considerable resources, are difficult to conduct and are rare.<sup>57,63,64,68</sup> There is a relative scarcity of personnel and neuroimaging machines in most regions of Africa, particularly in rural communities. The long distances needed to travel to seek the standard diagnostic approach to stroke care could worsen the condition with associated risk of aspiration. Most patients who would have been candidates for thrombolysis would have missed the opportunity because of the delay in diagnosis. For ethical reasons and putting the patients' survival first, in critical situations, diagnosis of stroke could be made in retrospect with pathological evidence at autopsy or neuroimaging at the nearest local facility when the patients are stable.

#### 4.8 | Significance of methodological deficiencies

The differences in epidemiologic indices may be attributable to disparities in methodological rigor. For instance:

- **Prevalence:** There are several population-/community-based studies reporting crude prevalence rates of stroke survivors ranging from 15 per 100 000 in Ethiopia<sup>57-59</sup> to 963 per 100 000 in Egypt<sup>10,60</sup> and 1460 per 100 000 in the Niger Delta region, Nigeria.<sup>9</sup> The wide disparity in these figures could reflect the uneven methodological rigor of the studies even after accounting for geographical and period effects. Therefore, prevalence, which depends on stroke incidence, duration, and mortality, is best estimated from studies that also track first-ever stroke and survival.<sup>57,61</sup>
- **Incidence:** Scant data from population-based studies showed crude incidence rates that ranged from 25 per 100 000 person-years in Lagos Nigeria,<sup>38,43,57,58</sup> to 250 per 100 000 person-years in Al-Kharga, Egypt, in 2007.<sup>57,58,62</sup> This wide disparity is likely caused by variability in methodological rigor and case ascertainment.<sup>57,58,63,64</sup> The latter study was more rigorous, while the Lagos study was only for 1 year, with underrepresentation of patients with stroke.
- **Mortality:** Mortality data obtained in Africa are usually not from standard vital statistics registration, but are predominantly gathered from verbal autopsy studies, police reports, sibling histories, and burial and mortuary reports.<sup>65,66</sup>
- **Trends:** Unfortunately, no rigorously conducted community-based stroke epidemiologic study has been performed at least twice in the same location to provide direct data on the magnitude of change in stroke burden in Africa.

#### 4.9 | African Rigorous Innovative Stroke Surveillance

To model the deployment of the recommended solutions listed above, a North-South collaborative stroke research team has designed an innovative stroke surveillance study: ARISES (African Rigorous Innovative Stroke Surveillance). ARISES aims to conduct a 3-year surveillance of stroke cases in selected urban and rural sites in Nigeria, which have an existing demographic surveillance system. Clinical and laboratory assessments will utilize an existing network of neurologists, radiologists, and hospitals from earlier SIREN<sup>17</sup> and Tailored Hospital-based Risk reduction to Impede Vascular Events after Stroke (THRIVES)<sup>48</sup> studies. ARISES also incorporates innovations such as the pictographic Questionnaire for Verifying Stroke-Free Status for screening and verifying stroke or stroke-free phenotype.<sup>45,51,53-56</sup> All study participants will be investigated using CT/MRI to confirm and classify stroke subtype according to a standard protocol, while imaging data from the study will be archived using AIM on Clear Canvas Enriched Stroke-Phenotyping Software,<sup>67</sup> a unique software package. The project will develop an innovative community-based interactive Stroke Information and Surveillance System for reliable measurement and tracking of the population burden of stroke, as well as discovery and quantification of the factors influencing it, while simultaneously building sustainable capacity for improving stroke literacy, research, and control in Nigeria. ARISES will provide vital burden update information against which existing Global Burden of Disease stroke estimates can be validated. Finally, the study will provide long-term benefit for stroke research and wider noncommunicable disease research in the target populations.

### 5 | CONCLUSIONS

The identifiable deficiencies in the methodology of stroke epidemiological studies in Africa are inaccurate and incomplete case ascertainment and classification, poor representation of the population, and insufficient period of study, as well as incorrect denominator population. No epidemiologic study is ideal, but following the standard criteria with the aid of modern investigation modalities,<sup>68</sup> reliable epidemiological indices for strategic primary, and secondary stroke prevention measures can be achieved. Innovative measures leveraging available information and communication technology infrastructure are recommended to facilitate rigorous epidemiological studies for accurate stroke surveillance in Africa and other low- and middle-income countries. These novel resources will facilitate the implementation and evaluation of hypertension and stroke control interventions in Africa in synergy with the H3Africa program.<sup>69</sup>

#### DISCLOSURES

Mayowa Owolabi, Bruce Ovbiagele, Paul Olowoyo, Daniel Lackland, Carolyn Jenkins, Oyedunni Arulogun, Rufus Akinyemi, Onoja Akpa, Oduunayo Akinyemi, Olanrewaju Olaniyan, Ezinne Uvere, Issa Kehinde, Mulugeta Gebregziabher, and Raelle Tagge are supported by U54 HG007479 and U01 NS079179 from the National Institutes of Health.



## CONFLICTS OF INTEREST

The authors declare no conflicts of interest.

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See supplementary material for references 40 to 98.

## SUPPORTING INFORMATION

Additional Supporting Information may be found online in the supporting information tab for this article.

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