



Patient-level and system-level determinants of stroke fatality across 16 large hospitals in Ghana and Nigeria: a prospective cohort study

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Summary

Background Every minute, six indigenous Africans develop new strokes. Patient-level and system-level contributors to early stroke fatality in this region are yet to be delineated. We aimed to identify and quantify the contributions of patient-level and system-level determinants of inpatient stroke fatality across 16 hospitals in Ghana and Nigeria.

Methods The Stroke Investigative Research and Educational Network (SIREN) is a multicentre study involving 16 sites in Ghana and Nigeria. Cases include adults (aged ≥ 18 years) with clinical and radiological evidence of an acute stroke. Data on stroke services and resources available at each study site were collected and analysed as system-level factors. A host of demographic and clinical variables of cases were analysed as patient-level factors. A mixed effect log-binomial model including both patient-level and system-level covariates was fitted. Results are presented as adjusted risk ratios (aRRs) with respective 95% CIs.

Findings Overall, 814 (21·8%) of the 3739 patients admitted with stroke died as inpatients: 476 (18·1%) of 2635 with ischaemic stroke and 338 (30·6%) of 1104 with intracerebral haemorrhage. The variability in the odds of stroke fatality that could be attributed to the system-level factors across study sites assessed using model intracluster correlation coefficient was substantial at 7·3% (above a 5% threshold). Stroke units were available at only five of 16 centres. The aRRs of six patient-level factors associated with stroke fatality were: low vegetable consumption, 1·19 (95% CI 1·07–1·33); systolic blood pressure, 1·02 (1·01–1·04) for each 10 mm Hg rise; stroke lesion volume more than 30 cm³, 1·48 (1·22–1·79); National Institutes of Health Stroke Scale (NIHSS) score, 1·20 (1·13–1·26) for each 5-unit rise; elevated intracranial pressure, 1·75 (1·31–2·33); and aspiration pneumonia, 1·79 (1·16–2·77).

Interpretation Studies are needed to assess the efficacy of interventions targeting patient-level factors such as aspiration pneumonia in reducing acute stroke fatality in this region. Policy directives to improve stroke unit access are warranted.

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Introduction

Every minute, six indigenous Africans develop new strokes.¹ This grim statistic is unfolding in a century in which improvements in acute stroke care are unparalleled compared with any time in modern history. In sub-Saharan Africa, up to 40% of patients die within 30 days of stroke, and 84% are dead within 3 years of a stroke diagnosis.^{1–4} On average, stroke affects an indigenous African approximately 15 years younger than comparator populations in high-income countries.^{5,6} For a medical disorder with well established modifiable risk factors,^{7–8} and effective treatment modalities, the high

rates of post-stroke mortality on the African continent are unacceptable. The poor outcomes of stroke in Africa are due to several factors, including inadequate health infrastructure, non-existent care pathways, a shortage of neurologists to coordinate stroke care, and a lack of awareness of stroke symptoms among patients and even clinicians.⁹

Improving outcomes of acute stroke admissions across Africa is an urgent imperative. First, a clear understanding of the patient-related predictors of acute stroke fatality is needed to help tailor management algorithms to avert stroke deaths. Second, an appraisal of system-related

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For the Yoruba translation of the abstract see [Online](#) for appendix 2

For the Hausa translation of the abstract see [Online](#) for appendix 3

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Research in context

Evidence before this study

Early mortality after stroke in sub-Saharan African countries is unacceptably high. Single-centre studies with limited sample sizes in the region have focused on patient-level determinants of case fatality without contemporaneous evaluation of system-level factors. Consequently, patient-level and system-level contributors to early stroke mortality in this region are yet to be delineated. We performed a literature search of articles in English published between Jan 1, 1990, and Jan 1, 2022, on multicentre studies assessing patient-level and system-level factors associated with stroke fatality in Africa. Our search identified the INTERSTROKE study which had representation from African hospitals. Data from 108 hospitals with 12 300 patients with stroke in the INTERSTROKE observational study showed that patients from resource-limited countries had more severe strokes and intracerebral haemorrhages, poorer access to stroke services, and used fewer investigations and treatment than resource-replete countries. However, there was a smaller representation of indigenous African patients and hospitals in INTERSTROKE compared with our study.

Added value of this study

Overall, 22% of patients with stroke died on admission, with a lower case fatality among ischaemic strokes at 18.1% compared with 30.6% for intracerebral haemorrhage. We found that availability of stroke services and resources across 16 large hospitals contributed to 7.3% of the variability in stroke mortality. Stroke units, an evidence-based stroke service intervention, were available only at five of 16 participating centres. Six patient-level factors—namely low vegetable consumption, elevated systolic blood pressure at presentation, larger lesion volumes, raised intracranial pressure, stroke severity, and aspiration pneumonia—independently predicted early fatality.

Implications of all the available evidence

A mix of patient characteristics and system-level barriers in 16 hospitals in west Africa provide potential actionable points to address the high stroke fatality across hospitals in Africa. Development of local, context-attuned protocols for screening and management of swallowing abnormalities and blood pressure management, along with establishment of stroke units, are urgent priorities in this region.

factors such as stroke services availability within hospitals is also required to help identify gaps for resource allocation for optimal stroke care. Third, a focused and concerted engagement with policy makers by patient advocate groups, researchers, and clinicians is required to provide the needed framework to reverse the dire outcomes of stroke in the region. Previous studies on stroke fatality in Africa have been limited by being single-centre studies, lack of detailed phenotypic characterisation of stroke, and lack of data on stroke service indicators. We therefore sought to assess the determinants of acute stroke fatality by presenting data on patient-level and system-level factors across 16 large hospitals in Ghana and Nigeria serving an estimated population of 18 million inhabitants. Our primary focus was to identify and quantify the baseline determinants of stroke fatality overall, with subanalysis stratified by sex, age, and stroke type.

Methods

Study design and participants

The Stroke Investigative Research and Educational Networks (SIREN) study is a multicentre study involving 16 medical centres in Ghana and Nigeria. Ghana has five tertiary medical centres in total, of which two (40%) participated in the study, while Nigeria has 54 tertiary medical centres, of which 13 (24%) participated in the study (in addition to one secondary centre). Although SIREN was a case-control study, both cases and controls were followed up and covariates measured at 3-month, 9-month, and 12-month intervals. Patients with acute stroke (cases) were all enrolled on admission and monitored until death or discharge alive from the

hospital. Hence, stroke fatality is our outcome measure in this cohort study. The current analysis focuses mainly on assessing which baseline characteristics of patients with stroke were associated with fatality outcome at hospitalisation, without interest in the longitudinal analyses of results at multiple points in time. In brief, the current analysis is a prospective cohort study of all stroke cases admitted to the study hospitals; fatality, the study outcome (but not study covariates), was monitored daily until death or discharge from the hospital. A detailed protocol has been previously published and a summary provided below.¹⁰ For the STROBE checklist see appendix 4 (pp 3–8).

Stroke cases were consenting (in unconscious or aphasic patients, consent from next of kin was obtained) adults aged 18 years or older. To be eligible for enrolment, patients must have presented to hospital within 8 days of symptom onset (or within 8 days of when they were last seen without deficit), and had neuroimaging confirmation (CT scan or MRI) within 10 days of symptom onset. Patients with stroke were recruited from hospitals to ensure rapid and accurate phenotyping. Controls were stroke-free community-based adults (aged ≥ 18 years) from different localities in Nigeria and Ghana who were matched to cases for age (plus or minus 5 years), sex, and ethnicity.¹⁰ Ethical approval was obtained from all study sites and written informed consent was obtained from all participants (or their next of kin).¹⁰

Data collection

Basic demographic, socioeconomic, lifestyle (including cigarette smoking and alcohol use), physical activity,

Location	Stroke unit	MRI scan	Angio-graphy	Carotid doppler	Echo-cardio-graphy	Holter	Speech therapy	OT	IVT	MT	NSD	Total site score*	Study participants enrolled			Case fatality at site		
													Overall (n=3739)	Ischaemic stroke (n=2635)	Intracerebral haemorrhage (n=1104)	Overall (n=814)	Ischaemic stroke (n=476)	Intracerebral haemorrhage (n=338)
1. Korle-Bu Teaching Hospital, Accra, Ghana	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	No	No	20	534 (14.3%)	328 (12.4%)	206 (18.7%)	70 (13.1%)	28 (8.5%)	42 (20.4%)
2. Komfo Anokye Teaching Hospital, Kumasi, Ghana	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	No	No	20	687 (18.4%)	415 (15.7%)	272 (24.6%)	182 (26.5%)	102 (24.6%)	80 (29.4%)
3. University College Hospital, Ibadan, Nigeria	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	No	Yes	20	405 (10.8%)	255 (9.7%)	150 (13.6%)	206 (50.9%)	118 (46.3%)	88 (58.7%)
4. University of Ilorin Teaching Hospital, Ilorin, Nigeria	Yes	Yes	Yes	Yes	Yes	Yes	No	No	No	No	No	19	350 (9.4%)	258 (9.8%)	92 (8.3%)	71 (27.5%)	37 (14.3%)	34 (37.0%)
5. Obafemi Awolowo University Teaching Hospital, Ile-Ife, Nigeria	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	No	Yes	20	202 (5.4%)	140 (5.3%)	62 (5.6%)	23 (11.4%)	12 (8.6%)	11 (17.7%)
6. Ahmadu Bello University, Zaria, Nigeria	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	No	No	No	19	523 (14.0%)	460 (17.5%)	63 (5.7%)	72 (13.8%)	56 (12.2%)	16 (25.4%)
7. Aminu Kano Teaching Hospital, Kano, Nigeria	No	Yes	Yes	Yes	Yes	Yes	No	No	No	No	No	17	267 (7.1%)	199 (7.6%)	68 (6.2%)	20 (7.4%)	13 (6.5%)	7 (10.3%)
8. Jos University Teaching Hospital Jos, Nigeria	No	No	No	Yes	No	Yes	Yes	Yes	No	No	Yes	17	123 (3.3%)	83 (3.1%)	40 (3.6%)	16 (13.8%)	12 (14.5%)	4 (10.0%)
9. Blossom Medical Center, Ibadan, Nigeria	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	No	Yes	21	16 (0.4%)	16 (0.6%)	0	0	0	0
10. Federal Medical Center, Abeokuta, Nigeria	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	No	Yes	20	224 (6.0%)	165 (6.3%)	59 (5.3%)	70 (31.3%)	44 (26.7%)	26 (44.1%)
11. Sacred Heart Hospital, Abeokuta, Nigeria	No	No	No	No	Yes	Yes	Yes	No	No	No	No	14	133 (3.6%)	100 (3.8%)	33 (3.0%)	24 (18.0%)	17 (17.0%)	7 (21.2%)
12. Federal Medical Center, Umuahia, Nigeria	No	Yes	No	Yes	Yes	No	Yes	Yes	No	No	No	17	31 (0.8%)	23 (0.9%)	8 (0.7%)	8 (25.8%)	5 (21.7%)	3 (37.5%)
13. Ladoke Akintola University of Technology Hospital, Ogbomoshosho, Nigeria	No	Yes	No	Yes	Yes	No	Yes	Yes	No	No	No	17	11 (0.3%)	9 (0.3%)	2 (0.3%)	5 (45.5%)	4 (44.4%)	1 (50.0%)
14. Delta State University Teaching Hospital, Oghara, Nigeria	No	Yes	No	Yes	Yes	No	Yes	Yes	No	No	No	17	91 (2.4%)	67 (2.5%)	24 (2.2%)	24 (26.4%)	12 (17.9%)	12 (50.0%)
15. Federal Teaching Hospital Ido-Ekiti, Nigeria	No	Yes	Yes	Yes	Yes	Yes	No	Yes	No	No	Yes	19	58 (1.6%)	44 (1.7%)	14 (1.3%)	4 (6.9%)	2 (4.5%)	2 (14.3%)
16. Federal Medical Center, Owo, Nigeria	No	Yes	No	Yes	Yes	Yes	No	Yes	No	No	No	17	84 (2.2%)	73 (2.8%)	11 (1.0%)	19 (22.6%)	14 (19.1%)	5 (45.5%)
Total†	..	..	..	..	..	..	..	..	..	..	..	..	3739 (70.0%)	2635 (70.0%)	1104 (30.0%)	814 (21.8%)	476 (18.2%)	338 (30.2%)

All facilities were tertiary level centres, except Blossom Medical Center, Ibadan, Nigeria, which was a secondary level centre. All sites had CT scan machines, electrocardiography machines, a neurologist, cardiologist, and physiotherapist (personnel), and the following medications: antihypertensives, oral hypoglycaemics, insulin, antiplatelets, anticoagulants, statins, and mannitol (not shown in the table). OT=occupational therapy. IVT=intravenous thrombolytic therapy. MT=mechanical thrombectomy. NSD=neurosurgical decompression. *Out of 23 items. †The denominator for all percentages in the Total row is 3739 (the total number of study participants).

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See Online for appendix 4

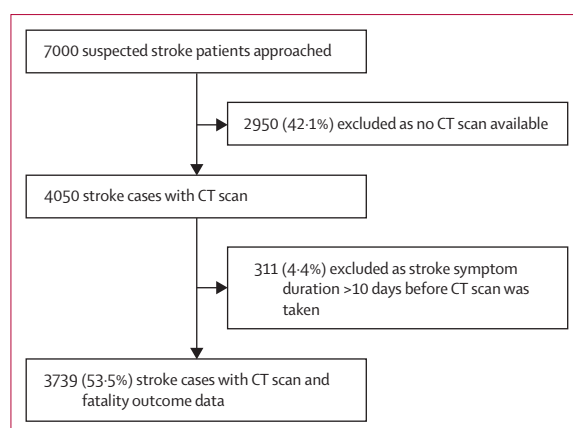


Figure: Flow chart for stroke cases included in the analysis

dietary, psychosocial stress, and depression information was obtained by self-report using questionnaires administered by research assistants. Blood samples for glycated haemoglobin (HbA_{1c}), and early morning samples after overnight fast in cases (post-acute phase when fasting is feasible) for measurement of fasting lipid panel (total cholesterol, HDL cholesterol, LDL cholesterol, and triglycerides) and fasting glucose, were obtained following a uniform standard operating procedure across all study sites. We assessed stroke severity using the National Institutes of Health Stroke Scale (NIHSS). All stroke cases were followed up until discharge from hospital or death during hospitalisation.

Definition of risk factors and outcome measures

Diabetes was defined using either a history of diabetes, use of medications for diabetes, an elevated HbA_{1c} ($\geq 6.5\%$), or a fasting blood glucose concentration of 7.0 mmol/L or higher taken after 7 days for stroke cases due to stress-induced transient rise in plasma glucose.¹¹

For hypertension, the average of three blood pressure measurements was obtained at baseline and daily for 7 days or until death.¹² Hypertension was defined as a blood pressure of 140/90 mm Hg or higher at 72 h after stroke, a history of hypertension, or use of anti-hypertensive drugs before stroke or more than 72 h after stroke.

Dyslipidaemia was defined as either a fasting total cholesterol of 5.2 mmol/L or higher, LDL cholesterol of 3.4 mmol/L or higher, HDL cholesterol of 1.03 mmol/L or lower, or triglycerides of 1.7 mmol/L or higher in accordance with National Cholesterol Education Program guidelines,¹³ or use of a statin before stroke onset.

Cardiac disease was defined on the basis of either a history, clinical examination and electrocardiogram, or echocardiographic evidence of cardiac arrhythmias (mainly atrial fibrillation or flutter, heart failure, cardiomyopathy, or valvular heart diseases).

Individuals with a waist-to-hip ratio of 0.90 for men and 0.85 for women or a BMI ≥ 30 kg/m² were classified

as obese using WHO cutoffs.¹⁴ Individuals were classified as physically active if they were regularly involved in moderate exercise (walking or cycling) or strenuous exercise (jogging, farming, and carrying water long distances) for 4 h or more per week.¹²

For dietary history, the regularity of consumption of food items such as green leafy vegetables, meat, fish, nuts, sugar, and other local staple food items, and addition of salt at the table, was classified as daily, weekly, at least once monthly, and none in a month, based on self-report.

For alcohol use, participants were categorised as current users (users of any form of alcoholic drinks) or never or former drinkers, based on self-report. We dichotomised alcohol intake as low (1–3 drinks per day for men and 1–2 drinks per day for women) and high if consumption exceeded these sex-specific cutoffs.¹² For smoking status, participants were defined as current smokers (individuals who smoked any tobacco in the past 12 months), former smokers (stopped for >12 months), or never smokers.

Regarding psychosocial factors, psychosocial stress was assessed by self-report of stress at home or work or life events in the 2 weeks before stroke; depression was assessed by asking about the presence of depressed mood in the 4 weeks before stroke.¹²

Family history of cardiocerebrovascular disease was defined on the basis of self-reported history of any of hypertension, diabetes, stroke, or cardiac disease in a participant's father, mother, sibling, or second-degree relative.

Neuroradiological markers of raised intracranial pressure (ICP) were mid-line shift and intracranial herniations including subfalcine, transtentorial, and tonsillar herniations. Infarct or haematoma volume was calculated using the ABC/2 method, whereby A is the largest diameter of the lesion on the CT slice with the largest lesion area (selected by eye), B is the diameter perpendicular to A, and C is the total number of CT slices containing the lesion multiplied by slice thickness.

Aspiration pneumonia was defined as a chest infection occurring after stroke onset.

Evaluation of stroke services and resources at study sites

We used a questionnaire to gather data on the availability of 23 stroke services and resources in 2019. These included the availability of CT or MRI scans, angiography, electrocardiography, echocardiography, carotid doppler ultrasonography, stroke unit, intravenous thrombolysis, mechanical thrombectomy, and neurosurgical decompression therapy for severe strokes. Other services assessed included the availability of physiotherapy, occupational therapy, and speech therapy for post-stroke rehabilitation. Medications assessed for availability included antihypertensives, insulin and oral hypoglycaemics, antiplatelets, anticoagulants, statins, and

	Alive at discharge (n=2925)	Died (n=814)	p value
Demographic characteristics			
Sex			
Male	1640 (56.1%)	464 (57.0%)	0.61
Female	1285 (43.9%)	350 (43.0%)	..
Age, years	59.5 (14.1)	60.9 (15.1)	0.0001
Monthly income >US\$100	1609 (55.0%)	429 (52.7%)	0.25
Educational status			
None or primary	1125 (38.5%)	305 (37.5%)	0.03
Secondary	817 (27.9%)	264 (32.4%)	..
Tertiary or higher	974 (33.3%)	243 (29.9%)	..
Location of domicile			
Urban	1783 (61.0%)	518 (63.6%)	0.41
Semi-urban	864 (29.5%)	223 (27.4%)	..
Rural	266 (9.1%)	72 (8.8%)	..
Country			
Nigeria	1954 (66.8%)	559 (68.7%)	0.32
Ghana	971 (33.2%)	255 (31.3%)	..
Primary occupation			
Highly skilled, skilled, or semi-skilled	1151 (39.4%)	345 (42.4%)	0.10
Manual	656 (22.4%)	191 (23.5%)	..
Retired	535 (18.3%)	156 (19.2%)	..
Unemployed	149 (5.1%)	38 (4.7%)	..
Other	264 (9.0%)	51 (6.3%)	..
Vascular risk factors			
Hypertension	2797 (95.6%)	786 (96.6%)	0.13
Diabetes	1125 (38.5%)	296 (36.4%)	0.28
Dyslipidaemia	2467 (84.3%)	635 (78.0%)	<0.0001
Tobacco use (any use)	277 (9.5%)	74 (9.1%)	0.70
Alcohol use (current use)	926 (31.7%)	261 (32.1%)	0.84
Waist-to-hip ratio	0.94 (0.1)	0.94 (0.1)	0.0031
Waist-to-hip ratio raised	2268 (77.5%)	646 (79.4%)	0.10
Waist-to-hip ratio by thirds			
≤0.90	729 (24.9%)	186 (22.9%)	0.48
0.91–0.96	1007 (34.4%)	292 (35.9%)	..
≥0.97	1014 (34.7%)	283 (34.8%)	..
Cardiac disease, any	351 (12.0%)	77 (9.5%)	0.047
Stress	537 (18.4%)	135 (16.6%)	0.26
Depression	214 (7.3%)	52 (6.4%)	0.41
Adding salt at the table	196 (6.7%)	63 (7.7%)	0.26
Low consumption of green leafy vegetables	658 (22.5%)	312 (38.3%)	<0.0001
Meat consumption	2034 (69.5%)	547 (67.2%)	0.69
Family history of stroke	473 (16.2%)	87 (10.7%)	<0.0001
Clinical characteristics at presentation			
Headache	1206 (41.2%)	362 (44.5%)	0.038
Vomiting	521 (17.8%)	232 (28.5%)	<0.0001
Disturbed consciousness	1052 (36.0%)	520 (63.9%)	<0.0001
Seizure	254 (8.7%)	115 (14.1%)	<0.0001
Focal neurologic deficit	1906 (65.2%)	19.4 (2.4%)	<0.0001
Previous stroke	281 (9.6%)	76 (9.3%)	0.82

(Table 2 continues in next column)

	Alive at discharge (n=2925)	Died (n=814)	p value
(Continued from previous column)			
Blood pressure at presentation			
Systolic	156.1 (29.5)	166.5 (34.3)	<0.0001
Diastolic	94.2 (17.6)	105.2 (17.7)	0.0040
Laboratory characteristics			
Haematocrit (%)	27.9 (7.4)	27.8 (3.8)	0.39
Mean corpuscular volume, fL	83.2 (20.1)	82.3 (8.8)	0.45
Platelets, $\times 10^3/\mu\text{L}$	350.9 (72.8)	206.6 (87.6)	0.20
HDL cholesterol, mg/dL	47.6 (19.3)	47.6 (19.9)	0.55
LDL cholesterol, mg/dL	120.8 (51.7)	118.3 (49.6)	0.07
Total cholesterol, mg/dL	190.5 (57.5)	188.7 (57.5)	0.22
Triglycerides, mg/dL	123.5 (82.4)	129.5 (77.4)	0.52
Serum creatinine, mg/dL	1.8 (8.7)	1.9 (3.3)	0.91
Random blood glucose at admission, mg/dL	116.0 (49.1)	126.9 (55.5)	0.0088
Urea, mg/dL	42.0 (118.3)	52.3 (51.9)	0.092
Neuroradiological correlates			
Stroke type			
Ischaemic	2159 (73.8%)	476 (58.5%)	<0.0001
Intracerebral haemorrhage	766 (26.2%)	338 (41.5%)	..
Volume of lesion, cm^3			
<10	1476 (50.5%)	270 (33.2%)	<0.0001
10–30	478 (16.3%)	151 (18.6%)	..
>30	365 (12.5%)	238 (29.2%)	..
Location of lesion			
Haemorrhagic stroke			
Lobar	164 (5.6%)	61 (7.5%)	0.14
Non-lobar	546 (18.7%)	260 (31.9%)	..
Stroke aetiology			
Ischaemic stroke			
TOAST classification			
Large vessel atherosclerosis	583 (19.9%)	163 (20.0%)	<0.0001
Small-vessel occlusion or lacunar	637 (21.7%)	94 (11.5%)	..
Cardioembolic	126 (4.3%)	29 (3.6%)	..
Other	817 (27.9%)	190 (23.3%)	..
OCSP classification			
Total anterior circulation infarct	227 (7.8%)	88 (10.8%)	<0.0001
Partial anterior circulation infarct	577 (19.7%)	126 (15.5%)	..
Posterior circulation infarct	189 (6.5%)	36 (4.4%)	..
Lacunar infarct	741 (25.3%)	134 (16.5%)	..
Haemorrhagic stroke			
SMASH-U aetiological classes			
Structural	23 (0.8%)	13 (1.6%)	0.62
Medication-associated	3 (0.1%)	2 (0.2%)	..
Amyloid angiopathy	7 (0.2%)	5 (0.6%)	..
Systemic diseases	4 (0.1%)	0 (0.0%)	..

(Table 2 continues in next column)

	Alive at discharge (n=2925)	Died (n=814)	p value
(Continued from previous column)			
Hypertension	555 (19.0%)	237 (29.1%)	..
Undetermined	17 (0.6%)	6 (0.7%)	..
Stroke severity indicators			
NIHSS score	12.3 (9.6)	24.7 (12.4)	<0.0001
Stroke Levity Scale	6.7 (4.3)	3.3 (2.9)	<0.0001
Modified Rankin score	3.7 (1.2)	4.6 (0.8)	<0.0001
Use of vascular preventive medicines before stroke			
Antihypertensives	1469 (50.2%)	360 (44.2%)	0.0045
Antiplatelets	471 (16.1%)	65 (8.0%)	<0.0001
Statins	188 (6.4%)	29 (3.6%)	0.0021
Antidiabetics	373 (12.8%)	92 (11.3%)	0.28
Anticoagulants	27 (0.9%)	15 (1.8%)	0.027
Hypouricosuric medications	12 (0.4%)	3 (0.4%)	0.87
Medical treatments instituted on admission			
Antiplatelets	1585 (54.2%)	283 (34.8%)	<0.0001
Anticoagulant after stroke	328 (11.2%)	102 (12.5%)	0.30
Heparin	121 (4.1%)	41 (5.0%)	0.27
Warfarin	63 (2.2%)	30 (3.7%)	0.013
Dabigatran	34 (1.2%)	8 (1.0%)	0.67
Rivaroxaban	50 (1.7%)	8 (1.0%)	0.14
Other	60 (2.1%)	15 (1.8%)	0.71
Cerebral decompression with osmotic therapy	1121 (38.3%)	471 (57.9%)	<0.0001
Antihypertensives	2443 (83.5%)	634 (77.9%)	0.0043
Antioxidants	1022 (34.9%)	207 (25.4%)	<0.0001
Insulin	293 (10.0%)	103 (12.7%)	0.034
Oral hypoglycaemic agents	517 (17.7%)	119 (14.6%)	0.071
Statins	1547 (52.9%)	297 (36.5%)	<0.0001
Physiotherapy	2036 (69.6%)	527 (64.7%)	0.0034
Anti-embolism stockings	585 (20.0%)	284 (34.9%)	<0.0001
Speech therapy	318 (10.9%)	59 (7.2%)	0.0018
Documented complications			
Raised intracranial pressure	343 (11.7%)	338 (41.5%)	<0.0001
Aspiration pneumonia	303 (10.4%)	334 (41.0%)	<0.0001
Deep venous thrombosis	64 (2.2%)	70 (8.6%)	<0.0001
Pulmonary thromboembolism	16 (0.5%)	12 (1.5%)	0.0032
Arrhythmias	54 (1.8%)	66 (8.1%)	<0.0001
Seizure disorder	130 (4.4%)	99 (12.2%)	<0.0001
Urinary tract infection	188 (6.4%)	64 (7.9%)	0.052
Decubitus ulcers	82 (2.8%)	67 (8.2%)	<0.0001
Depression	200 (6.8%)	24 (2.9%)	<0.0001
Dementia	31 (1.1%)	7 (0.9%)	0.73
Parkinsonism	26 (0.9%)	4 (0.5%)	0.32
Duration of symptoms and admission			
Duration of stroke symptoms before presentation, days	1.0 (0.0–4.0)	1.0 (0.0–3.0)	<0.0001
Duration of admission, days	11.0 (7.0–19.0)	8.0 (5.0–16.0)	<0.0001

(Table 2 continues in next column)

	Alive at discharge (n=2925)	Died (n=814)	p value
(Continued from previous column)			
Health facilities			
Stroke unit			
Not available	1210 (41.4%)	419 (51.5%)	<0.0001
Available	1715 (58.6%)	395 (48.5%)	..
Data are n (%), mean (SD), or median (IQR). TOAST=Trial of ORG 10172 in Acute Stroke Treatment. OCSF=Oxfordshire Community Stroke Project. NIHSS=National Institutes of Health Stroke Scale.			
Table 2: Comparison of characteristics of patients with stroke in Ghana and Nigeria by fatality status			

mannitol. A site facility score was created by adding up the number of stroke services and resource items available per site out of the 23 items assessed.

Statistical analysis

The χ^2 test was used to assess bivariate associations between stroke mortality (case fatality) and clusters of potential baseline determinants (patients' demographic factors, clinical and laboratory characteristics, cardiovascular risk factors, neuroradiological correlates, stroke aetiologies, treatments instituted during admission, and documented complications). All patient-level covariates were baseline characteristics with no frequent missing data. Due to the site clustering in mortality risks, a mixed effect log-binomial model with random intercept was implemented to investigate whether the site-level characteristics such as having a stroke unit on site influences mortality among patients with stroke. We assessed the proportion of the total variance in mortality that is attributable to the sites using the intraclass correlation coefficient (ICC) as a function of the site-level and the patient-level variances. A value of ICC greater than 5% was considered substantial and confirmatory of the need to conduct a mixed model with random intercept.^{15,16}

Using the mixed effect log-binomial model in STATA version 17, the analysis was carried out in three steps or models. Model I, the first step, was a null model with only the random intercept (and no explanatory variables), allowing for detection of a possible site dimension to mortality in patients with stroke. Model II was an adjusted analysis and included only the patient-level characteristics to examine the extent to which site-level differences in mortality are explained by the patient-level characteristics. The final step (Model III) consisted of both the patient-level and the site-level covariates and was an adjusted analysis. Covariates for all adjusted models (Models II and III) were carefully selected on the basis of a literature search, our clinical understanding of stroke mortality risk, and empirical evidence from our data (significant associations observed in bivariate analyses after Bonferroni adjustment). The adjusted

models included selected covariates depending on whether or not they were confirmed confounders in the bivariate analysis and whether or not they improved the model fit or increased the standard error of the parameter estimate of the primary exposure (stroke unit). The numerical covariates in our study (blood pressure, duration of stroke symptoms before presentation at the hospital, and NIHSS score) have been previously shown to be linearly associated with the hazard rate of case fatality rate of stroke in selected studies among indigenous Africans.^{17,18} Results are presented as adjusted risk ratios (aRRs) with respective 95% CIs. In our interpretation, we focused on aRR more than 1.05 or less than 0.95, to avoid differences that might not be clinically relevant, except for systolic blood pressure, which has a wide range of values over which increments might increase risk of stroke fatality.

The corrected Akaike information criterion (CAIC) and the Bayesian information criterion (BIC) were used for model fit assessment; a lower value of the CAIC and the BIC indicated a better model fit. Patient-level factors were retained in all analyses carried out on the overall sample and stratified by sex, age, and primary stroke type.

Role of the funding source

The funders of the study had no role in study design, data collection, data analysis, data interpretation, or writing of the report.

Results

Table 1 shows the stroke services and resources available across the 16 study sites and site scores out of the 23 items assessed. All the study sites had 12 of 23 items, namely a CT scan machine; electrocardiography; a neurologist, cardiologist, and physiotherapist; and antihypertensives, oral hypoglycaemics, insulin, antiplatelets, anticoagulants, statins, and mannitol. However, only five (31.3%) of the 16 sites had a stroke unit, an organised in-hospital facility staffed by a multidisciplinary team, with at least six beds devoted to the care of patients with stroke. None of the sites provided modern reperfusion therapies, namely intravenous thrombolysis and mechanical thrombectomy services.

We approached 7000 clinically suspected stroke cases and enrolled 3739 patients with stroke between 2014 and 2019 across 16 study sites (figure). Overall, 814 (21.8%) died as inpatients; table 1 shows a breakdown of stroke case fatality per site, by stroke type.

The mean age of those who died was 60.9 years (SD 15.1) versus 59.5 years (14.1) for those who survived. Approximately 42% of study participants had altered level of consciousness at presentation. Information on demographic and self-reported lifestyle behaviours was obtained by proxy in 2870 (76.8%) study participants, such as children of participants (31.6%), a spouse (23.2%), next of kin (18.0%), caregiver (3.6%), or friend (0.3%). The demographic features of stroke cases

	Null model (Model I)	Model with patient- level variables (Model II)	Model with patient- level and site-level variables (Model III)
Stroke type			
Ischaemic stroke (ref)	..	1	1
Intracerebral haemorrhage	..	0.92 (0.78–1.08)	0.92 (0.78–1.088)
Vascular risk factors			
Dyslipidaemia	..	0.83 (0.67–1.02)	0.83 (0.67–1.02)
Low consumption of green leafy vegetables	..	1.19 (1.07–1.33)	1.20 (1.07–1.33)
Family history of stroke	..	0.80 (0.65–1.00)	0.81 (0.65–1.00)
Systolic blood pressure at presentation, each 10 mm Hg rise	..	1.02 (1.01–1.04)	1.02 (1.01–1.04)
Lesion volume, cm ³			
<10 (ref)	..	1	1
10–30	..	1.29 (1.12–1.49)	1.29 (1.12–1.50)
>30	..	1.48 (1.22–1.79)	1.48 (1.22–1.79)
Measure of stroke severity			
NIHSS score, each 5-unit rise	..	1.20 (1.13–1.26)	1.20 (1.13–1.26)
Documented complications			
Raised intracranial pressure	..	1.75 (1.31–2.33)	1.75 (1.31–2.33)
Aspiration pneumonia	..	1.79 (1.16–2.77)	1.80 (1.17–2.76)
Deep venous thrombosis	..	1.23 (0.82–1.85)	1.23 (0.82–1.85)
Arrhythmias	..	0.97 (0.61–1.55)	0.97 (0.60–1.55)
Seizure disorder	..	1.22 (0.91–1.63)	1.22 (0.90–1.65)
Decubitus ulcers	..	1.19 (0.85–1.67)	1.19 (0.85–1.68)
Duration of stroke symptoms before presentation	..	0.99 (0.99–1.00)	0.99 (0.99–1.00)
Stroke unit	..	..	1.08 (0.55–2.11)
Intercept	0.18 (0.13–0.24)*	0.03 (0.01–0.05)	0.03 (0.02–0.05)
Random effect			
Contextual random variance (SE)	0.26 (0.10)	0.29 (0.12)	0.29 (0.11)
ICC	7.33%	8.10%	8.11%
Model fit statistics			
CAIC	3928.88	1753.49	1753.44
BIC	3941.33	1838.06	1838.00

Data are adjusted risk ratio (95% CI) unless otherwise stated. NIHSS=National Institutes of Health Stroke Scale. SE=standard error. ICC=intraclass correlation coefficient. CAIC=Corrected Akaike information criterion. BIC=Bayesian information criterion. *p<0.001.

Table 3: Determinants of stroke fatality in Ghana and Nigeria

such as sex, location of residence, monthly income, and primary occupation were comparable between those alive at discharge and those who died, although there was a trend for a lower proportion of those who died to have attained tertiary education (table 2). Fatality was significantly higher among those with intracerebral haemorrhage (338 [30.6%] of 1104) compared with ischaemic stroke (476 [18.1%] of 2635). Those who died were more likely than those alive at discharge to have documented stroke-related complications such as raised ICP (41.5% vs 11.7%), aspiration pneumonia (41.0% vs 10.4%), deep venous thrombosis (8.6% vs 2.2%), cardiac arrhythmias (8.1% vs 1.8%), and decubitus ulcers (8.2% vs 2.8%; table 2). Bivariate analysis for

	Null model (Model I)	Model with patient- level variables (Model II)	Model with patient- level and site-level variables (Model III)
Vascular risk factors			
Low consumption of green leafy vegetables	..	1.37 (1.08–1.73)*	1.38 (1.09–1.74)*
Systolic blood pressure at presentation, each 10 mm Hg rise	..	1.01 (0.96–1.05)	1.00 (0.96–1.05)
Lesion volume, cm ³			
<10 (ref)	..	..	..
10–30	..	1.14 (0.81–1.60)	1.60 (0.82–1.62)
>30	..	1.45 (1.03–2.02)†	1.46 (1.05–2.02)†
TOAST classification			
Large vessel atherosclerosis	..	..	..
Small-vessel occlusion or lacunar	..	0.96 (0.79–1.18)	0.98 (0.81–1.19)
Cardioembolic	..	0.82 (0.79–1.18)	0.83 (0.66–1.05)
Other	..	0.94 (0.75–1.17)	0.94 (0.75–1.18)
Measure of stroke severity			
NIHSS, each 5-unit rise	..	1.23 (1.16–1.30)‡	1.23 (1.16–1.30)‡
Use of vascular preventive medicines before stroke			
Antiplatelets	..	0.90 (0.67–1.22)	0.90 (0.67–1.21)
Medical treatments instituted on admission			
Antiplatelets	..	0.72 (0.58–0.88)*	0.72 (0.58–0.88)*
Antihypertensives	..	0.86 (0.57–1.29)	0.87 (0.58–1.29)
Antioxidants	..	0.76 (0.56–1.04)	0.73 (0.51–1.05)
Statins	..	0.95 (0.83–1.09)	0.98 (0.85–1.12)
Anti-embolism stockings	..	1.16 (0.88–1.53)	1.16 (0.87–1.55)
Documented complications			
Raised intracranial pressure	..	1.64 (1.30–2.07)‡	1.63 (1.28–2.08)‡
Aspiration pneumonia	..	2.01 (1.27–3.18)*	2.05 (1.30–3.23)*
Deep venous thrombosis	..	1.06 (0.62–1.81)	1.06 (0.63–1.79)
Pulmonary thromboembolism	..	1.27 (0.65–2.48)	1.29 (0.66–2.51)
Arrhythmias	..	1.02 (0.58–1.77)	1.02 (0.58–1.78)
Seizure disorder	..	0.93 (0.60–1.44)	0.94 (0.60–1.48)
Urinary tract infection	..	1.09 (0.788–1.51)	1.09 (0.78–1.53)
Decubitus ulcers	..	1.23 (0.72–2.10)	1.22 (0.72–2.08)
Stroke unit	..	..	1.47 (0.78–2.79)
Intercept	0.15 (0.11–0.20)‡	0.05 (0.02–0.11)‡	0.04 (0.01–0.09)‡
Random effect			
Contextual random variance (SE)	0.29 (0.11)	0.23 (0.13)	0.19 (0.15)
ICC	8.10%	6.54%	5.46%
Model fit statistics			
CAIC	2463.53	1053.56	1052.23
BIC	2475.29	1132.50	1131.17

Data are adjusted risk ratio (95% CI) unless otherwise stated. TOAST=Trials of ORG 10172 in Acute Stroke Treatment. NIHSS=National Institutes of Health Stroke Scale. SE=standard error. ICC=intraclass correlation coefficient. CAIC=Corrected Akaike information criterion. BIC=Bayesian information criterion. *p<0.01. †p<0.05. ‡p<0.001.

Table 4: Determinants of stroke fatality in Ghana and Nigeria stratified by stroke type (ischaemic stroke)

ischaemic stroke and intracerebral haemorrhage is shown in appendix 4 (pp 9–15).

Regarding determinants of stroke fatality, the nested regression models using non-automated forward stepwise procedures showed no multicollinearity among covariates included in the regression analyses (appendix 4

p 16). The results of the random intercept model or the null model for stroke mortality (Model I) in table 3 show there is significant variation in the risk of stroke fatality across sites (contextual random variance=0.26, p=0.023). Also, the variability in the risk of stroke fatality that could be attributed to sites (ICC=7.33%) is considered substantial. The results of the multilevel model with only the individual-level factors (Model II) show that six factors were associated with inpatient stroke fatality, namely low consumption of green leafy vegetables (aRR 1.19 [95% CI 1.07–1.33]), systolic blood pressure at presentation (aRR 1.02 [1.01–1.04] for each 10 mm Hg increase), lesion volume more than 30 cm³ (aRR 1.48 [1.22–1.79]), higher NIHSS score (aRR 1.20 [1.13–1.26] for each 5-unit rise), raised ICP (aRR 1.75 [1.31–2.33]), and aspiration pneumonia (aRR 1.79 [1.16–2.77]). We emphasise a relative risk of at least 1.02 for each 10 mm Hg rise in systolic blood pressure obtained from our regression analysis, given the wide range of systolic blood pressure over which increments can increase risk of stroke fatality. These six factors remained significantly associated with stroke fatality in the adjusted analysis of the individual-level and site-level characteristics (Model III) but availability of a stroke unit at the study site was not associated with fatality (aRR 1.08 [0.55–2.11]).

Six factors were independently associated with ischaemic stroke fatality, namely low consumption of green leafy vegetables, infarct volume more than 30 cm³, higher NIHSS score, use of antiplatelet therapy (protective association), raised ICP, and aspiration pneumonia (table 4). For intracerebral haemorrhage, volume of haemorrhage, NIHSS score, raised ICP, aspiration pneumonia, depression (protective association), and duration of stroke symptoms before presentation were six factors associated with fatality (table 5). By sex, we found six factors were independently associated with stroke fatality among men and four factors among women (appendix 4 pp 17–18). Among those younger than 50 years, we found that family history of stroke (protective association), stroke severity, raised ICP, deep venous thrombosis, and decubitus ulcers were associated with fatality (appendix 4 pp 19–20). Dyslipidaemia, low consumption of green leafy vegetables, higher admission systolic blood pressure, larger lesion volume, stroke severity, raised ICP, and aspiration pneumonia were associated with fatality among those aged 50 years or older.

Discussion

Approximately 22% of patients admitted into 16 hospitals in the SIREN study died of stroke and its complications as inpatients. This case fatality rate agrees closely with that from recently published meta-analytic data involving 34 362 indigenous Africans, where the 1-month pooled case fatality rate was 24.1% (95% CI 21.5–27.0).¹⁹ The case fatality rate from ischaemic stroke in our study was 18.1% (16.6–19.6), which is higher when compared with

the worldwide 1-month case fatality of 13·5% (12·3–14·7) reported by Zhang and colleagues in 2020.²⁰ The high case fatality from intracerebral haemorrhage of 30·6% (27·9–33·4) is comparable with existing data from low-income and middle-income countries on the basis of evidence from the Global Burden of Diseases, Injuries, and Risk Factors Study.²¹ These data should be interpreted with a caveat of potential referral bias whereby more severe cases of stroke are referred to the SIREN study sites.

There was homogeneity in study site characteristics, with respect to availability of skilled health personnel such as neurologists and cardiologists, investigative capabilities (CT or MRI scanners, cardiology work-up), and cardiovascular medications for stroke management. Almost 94% of study hospitals were tertiary medical centres. Yet, the lack of acute reperfusion interventions such as thrombolysis and mechanical thrombectomy was pervasive across sites. Furthermore, only five (31%) of the 16 sites had stroke units and 38% had neurosurgical decompressive services available on site. Stroke services and resources available at hospital sites explained up to 7·3% of the variability in the risk of stroke fatality. We acknowledge that patient-level characteristics across sites might also increase this variability, as shown in Model III, but theoretically, Model I does not capture this patient-level variability. Nevertheless, we found that the availability of stroke units per se did not mitigate fatality although it was significant in bivariate analysis. The INTERSTROKE investigators found that having access to a stroke unit irrespective of the economic level of a country was associated with improved survival without severe dependency.²² These differences might reflect the inadequacy of bed capacity and lack of infrastructure and equipment in our stroke units to meet the high burden of stroke admissions. Perhaps functional outcomes or long-term case fatality would better capture the benefit of stroke units in the context of Africa.

Among a host of patient-level factors assessed, six factors were independently associated with stroke fatality, namely low vegetable consumption, high systolic blood pressure at presentation, larger lesion volumes, raised ICP, stroke severity, and aspiration pneumonia. As a premorbid factor, low consumption of vegetables increased risk of stroke fatality by 19% (95% CI 7–33). Vegetable consumption is thought to mediate protective cardiovascular effects mainly via antioxidant and blood pressure-lowering mechanisms.^{23,24} In concert, higher systolic blood pressure at presentation increased fatality, with each 10 mm Hg rise associated with a 2% (1–4) higher risk of inpatient death. Although blood pressure elevation after a stroke might be reactionary to maintain cerebral perfusion pressure, excessive surges in blood pressure are deleterious and promote extensive cerebral oedema.²⁵ Accordingly, larger stroke lesion volumes incrementally increased stroke fatality by 29% (12–49) for lesions measuring 10–30 cm³ and by 48% (22–79) for

	Null model (Model I)	Model with patient- level variables (Model II)	Model with patient- level and site-level variables (Model III)
Established risk factors			
Low consumption of green leafy vegetables	..	1·22 (0·86–1·73)	1·28 (0·95–1·71)
Lesion volume, cm ³			
<10 (ref)	..	..	..
10–30	..	1·30 (0·95–1·77)	1·30 (0·93–1·81)
>30	..	1·60 (1·16–2·23)*	1·59 (1·16–2·20)*
Measure of stroke severity			
NIHSS, each 5-unit rise	..	1·13 (1·08–1·18)†	1·12 (1·08–1·15)
Medical treatments instituted on admission			
Cerebral decompression with osmotic therapy	..	1·05 (0·75–1·46)	1·05 (0·76–1·46)
Documented complications			
Raised intracranial pressure	..	1·78 (1·37–2·32)†	1·79 (1·38–2·33)†
Aspiration pneumonia	..	1·75 (1·29–2·37)†	1·78 (1·31–2·41)†
Deep venous thrombosis	..	1·29 (0·82–2·05)	1·31 (0·85–2·03)
Arrhythmias	..	0·91 (0·71–1·15)	0·93 (0·64–1·34)
Seizure disorder	..	1·21 (0·97–1·52)	1·22 (0·95–1·56)
Depression	..	0·47 (0·22–0·98)‡	0·47 (0·21–1·03)
Duration of stroke symptoms before presentation	..	0·99 (0·99–0·99)*	0·99 (0·99–0·99)*
Stroke unit	..	..	1·12 (0·70–1·79)
Intercept	0·27 (0·20–0·36)†	0·06 (0·04–0·10)†	0·06 (0·05–0·08)†
Random effect			
Contextual random variance (SE)	0·19 (0·83)	0·04 (0·10)	..
ICC	5·46%	1·20%	..
Model fit statistics			
CAIC	1440·72	740·12	740·00
BIC	1450·74	789·68	789·56

Data are adjusted risk ratio (95% CI) unless otherwise stated. NIHSS=National Institutes of Health Stroke Scale. SE=standard error. ICC=intraclass correlation coefficient. CAIC=Corrected Akaike information criterion. BIC=Bayesian information criterion. *p<0·01. †p<0·001. ‡p<0·05.

Table 5: Determinants of stroke fatality in Ghana and Nigeria stratified by stroke type (haemorrhagic stroke)

lesions larger than 30 cm³. In particular, lesions larger than 30 cm³ were associated with higher fatality risk in all subgroup analyses except those younger than 50 years. A raised ICP was associated with stroke fatality across all subgroups in sensitivity analyses. With limited access to neurosurgical decompressive intervention, the presence of raised ICP following a stroke in our settings is ominous. Furthermore, we observed that each 5-unit rise in the NIHSS score was associated with 20% (13–26) higher relative risk of fatality overall, an association which persisted among stroke types. Previous studies have demonstrated a very strong discriminative, graded near-linear relationship between first recorded NIHSS and higher 30-day mortality risk for ischaemic strokes.²⁶ In addition, other studies have now posited that the NIHSS score is an independent predictor for prognosticating outcomes of intracerebral haemorrhage as our study affirms.²⁷

In addition to the aforementioned factors, we identified six more factors associated with stroke fatality in specific subgroups, including antiplatelet use among patients with ischaemic stroke (protective; table 4), earlier time to presentation to hospital among patients with intracerebral haemorrhage (protective; table 5), family history of stroke (protective among males and those younger than 50 years), deep venous thrombosis and decubitus ulcers (adversely associated among those younger than 50 years), and dyslipidaemia (protective among those 50 years or older; appendix 4 pp 17–18). The use of antiplatelet therapy was associated with a 28% (95% CI 12–42) lower relative risk of fatality among those with ischaemic stroke in consonance with the INTERSTROKE study, in which there was a 39% (12–72) improvement in survival on antiplatelet therapy irrespective of other patient and service attributes.²²

Our study has important clinical and policy implications. The high prevalence of severe strokes and intracerebral haemorrhage necessitates investments in developing and strengthening emergency services to transport patients for urgent care. Setting up stroke units is now a necessity in all regional capitals and possibly district hospitals to provide emergency assessment and care for stroke patients. The excess deaths due to aspiration pneumonia, elevated blood pressure, and decubitus ulcers might be amenable to enacting appropriate protocols for screening for dysphagia after stroke, management of hypertension, and optimising nursing care.²⁸

The following limitations are worth noting. First, we only included patients who underwent a head CT scan within 10 days to determine the stroke type to be eligible for inclusion into our study. Thus, patients with clinically suspected strokes who died before neuroimaging or those who presented after 10 days of symptom onset were excluded. Secondly, 15 of the 16 study sites included were either referral or tertiary medical centres, which does not reflect the experiences at lower cadres of health-care delivery in Ghana and Nigeria. Thirdly, study sites were not randomly selected within the two countries. Fourthly, we had no data on the fraction of all stroke patients who died before reaching hospital. Due to these four reasons, the findings have limited generalisability. System-level factors were included in our models as an aggregate score assuming that each factor carried an equal weight. In addition, details of staff strength and functionality of equipment of stroke units were not assessed. Assessment of raised ICP using either direct ICP monitoring or indirect markers such as papilloedema would have improved upon the accuracy of evaluation of ICP as a factor associated with stroke fatality. These limitations notwithstanding, this is one of the largest and most comprehensive efforts at delineating the patient-level and system-level factors associated with acute stroke fatality in Africa.

Active engagement between advocacy groups such as patient support groups, care providers, and policy makers

is required to align emergency stroke care needs and policy priorities of health ministries in Africa. These are some of the core mandates of the African Stroke Organization.^{29,30} Implementation studies are particularly needed to critically assess the barriers and facilitators of stroke service provision gaps in Africa to produce workable solutions.

In conclusion, six patient characteristics—namely low vegetable consumption, high systolic blood pressure at presentation, larger lesion volumes, raised ICP, stroke severity, and aspiration pneumonia—are associated with stroke fatality among west Africans. Stroke services and resources such as stroke units were scarce. Development of local, context-attuned protocols for screening and management of aspiration pneumonia, blood pressure, and ICP, along with establishment of stroke units, might substantially reduce stroke fatality in this region. Clinical trials assessing the effects of interventions targeting patient-level determinants of acute stroke fatality in Africa are eagerly awaited.

Contributors

MOO and BO designed the study. FSS wrote the first draft of the manuscript. OMA and JOA performed data analyses. MOO and OMA accessed and verified the data. All other co-authors reviewed the manuscript and agreed to its submission. All authors had full access to all the data in the study and had final responsibility for the decision to submit for publication.

Declaration of interests

We declare no competing interests.

Data sharing

Participant level de-identified data are available from the study's Principal Investigator, MOO, and will be shared with investigators upon request via email to the corresponding author.

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