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Unmet Neurosurgical Needs in Stroke: Indications, Interventions and Outcomes of 250 Patients in Bouaké (Côte D'ivoire)

Running title: Unmet neurosurgical needs in stroke

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Abstract

Background. In sub-Saharan Africa, little is known about what happens to stroke patients when a neurosurgeon decides that an operation is needed. We followed this pathway from indication to procedure, hypothesizing that the bottleneck lies in delivering indications rather than identifying them.

Methods. Prospective cohort of 250 consecutive adults admitted for imaging-confirmed stroke at Bouaké University Hospital between 1 January 2022 and 31 December 2023. An unmet indication was an indication made but not followed by a procedure during admission. We used Fisher's exact test and logistic regression (Firth in case of separation).

Results. A surgical indication was made in 107 patients (42.8%; 95%CI 36.8–49.0) and surgery performed in 45 (18.0%): 62 indications (57.9%) went unanswered. Operated patients underwent 54 procedures (24 external ventricular drainages, 24 decompressive craniectomies, 6 haematoma evacuations); no aneurysm was treated. For the 37 unmet indications in intracerebral haemorrhage, the reason was material (money or theatre unavailable) in 16, deterioration or

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death before theatre in 7, and unknown in 10. In-hospital mortality was 24.0%: 16.8% without indication, 33.3% in operated patients, 33.9% with an unmet indication, at comparable baseline severity. After adjustment, unmet indication was not significantly associated with mortality (adjusted odds ratio, aOR 2.10 [0.92–4.78]; p=0.077), nor was surgery (aOR 1.60 [0.65–3.91]); the direct contrast gave an aOR of 1.31 [0.49–3.50]. Without the 7 patients who died or deteriorated before theatre, crude mortality in the group fell to 27.3% (15/55) and the aOR to 1.81 [0.76–4.28]. Good functional outcome at discharge (mRS ≤ 2) concerned 31.2% of patients, with no difference between pathways. Only subarachnoid haemorrhage predicted non-fulfilment.

Conclusion. The main problem is not spotting indications but honouring them, with access barriers as the main documented reason. Whether an unmet indication costs lives remains to be shown: the adjusted association is not significant, and part of the crude excess comes from patients who died or deteriorated before surgery.

Keywords: stroke; neurosurgery; intracerebral haemorrhage; unmet neurosurgical needs; access to care; decompressive craniectomy; global neurosurgery; sub-Saharan Africa; Côte d'Ivoire.

1. Introduction

Stroke is the second leading cause of death worldwide and one of the leading causes of disability. Sub-Saharan Africa bears a disproportionate share of this burden: incidence, in-hospital case fatality and sequelae there exceed those of high-income countries [1–4], owing to late diagnosis, poorly controlled risk factors and limited access to specialist care [5–7].
For the neurosurgeon, the haemorrhagic forms matter most: intracerebral haemorrhage (ICH) and subarachnoid haemorrhage (SAH). More frequent in Africa than in the West, with widespread and poorly controlled hypertension [5,6,8], their complications (ventricular flooding, hydrocephalus, mass effect) are the ones that call for a procedure [9–11].

Randomised trials have removed many certainties: STICH and STICH II showed no systematic benefit of evacuating supratentorial ICH [12,13], and minimally invasive techniques (MISTIE III, ENRICH) benefit only subgroups [14,15]; conversely, decompressive craniectomy markedly reduces mortality in malignant infarction [16]. But these trials come from centres equipped with advanced imaging, neurovascular units and neurocritical care, rarely all available in sub-Saharan African hospitals.

One question remains open: what becomes of a patient for whom a surgical indication is made but whom the system cannot operate on? The African literature mainly describes the characteristics of stroke or the outcomes of operated patients. To our knowledge, only our analysis of this cohort, devoted to a model predicting the indication, has reported the proportion of neurosurgical indications in stroke that lead to an intervention [17]; neither the reasons for non-fulfilment nor their relation to mortality were studied there.

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We used the same prospective cohort [17]. That article was devoted to predicting the indication and, for that purpose, reported the overall numbers of indications, operated patients and procedures, which we cite here without reanalysing them. The present article starts where [17] stopped, at the moment the indication is made: it studies whether the indication was fulfilled, the reasons for non-fulfilment, in-hospital mortality, functional outcome at discharge, complications and the factors associated with non-fulfilment, none of which was analysed in [17]. Our hypothesis: the main limit lies in delivering indications, not in identifying them.

2. Methods

2.1. Study design and setting

We analysed a prospective cohort of 250 consecutive adults admitted for stroke confirmed by CT or MRI to the neurosurgery department of Bouaké University Hospital, a referral hospital for a large area of central Côte d'Ivoire, from 1 January 2022 to 31 December 2023 (dates verified in the source database). Traumatic or tumoural haemorrhages and patients without imaging were excluded. Data collection and definitions are described in the article on the prediction model built on the same patients [17], which also reported the overall numbers of indications, operated patients and procedures reused here. The study follows the STROBE recommendations [18].

2.2. Neurosurgical decision-making and indication criteria

Every patient was assessed at admission by the neurosurgeon on call, who decided from the clinical examination and the initial CT or MRI whether a procedure was required. The elements taken into account were those of international recommendations [9–11,19]: level of consciousness and its course, clinical signs of herniation and, on imaging, hydrocephalus, intraventricular extension of the haemorrhage, mass effect with midline shift and, in ICH, haematoma volume. Table 1 gives the main situation leading to each procedure: external ventricular drainage for obstructive hydrocephalus or intraventricular extension of haemorrhage; decompressive craniectomy for malignant cerebral infarction; haematoma evacuation or decompressive craniectomy for mass effect or herniation; aneurysm treatment for subarachnoid haemorrhage from a ruptured aneurysm. No numerical threshold (haematoma volume, midline shift, Glasgow score) was fixed in advance: these criteria were applied case by case, and the decision could vary with the neurosurgeon on call and the clinical circumstances. In [17], the four elements independently associated with the indication in this cohort were hydrocephalus, mass effect, ventricular flooding and impaired consciousness, which is consistent with these criteria.

The indication was first assessed by the neurosurgeon on call, then discussed with a second neurosurgeon when the situation was complex or several therapeutic options were possible; in that case, the decision resulted from their discussion. It was recorded in the medical file at the initial neurosurgical assessment, before the procedure was carried out or abandoned, and without regard to the availability of the technical facilities, which conditions access to the procedure and not the decision: this is what allows the gap between the two to be measured. No written protocol

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or systematic multidisciplinary meeting existed over the period. The indications were not reviewed retrospectively by an independent neurosurgeon, and no interobserver agreement was measured; we return to this limitation in section 4.9.

Table 1: Indication criteria for the main neurosurgical procedures (indications made independently of the availability of the technical facilities).

Procedure	Main indication situation
External ventricular drainage	Obstructive hydrocephalus or intraventricular extension of haemorrhage
Decompressive craniectomy	Malignant cerebral infarction
Haematoma evacuation or decompressive craniectomy	Mass effect or cerebral herniation
Aneurysm treatment (clipping or embolisation)	Subarachnoid haemorrhage from a ruptured aneurysm

2.3. Definitions

Surgical indication was the decision, recorded at admission or during the course of the illness, that a neurosurgical procedure was required, irrespective of whether it was carried out. Surgical fulfilment identified the patients actually operated on. An unmet indication is an indication made but not followed by a procedure during hospitalisation. Only three procedures define operated status: decompressive craniectomy, haematoma evacuation and external ventricular drainage; thrombolysis, thrombectomy, clipping and embolisation were recorded separately. We recorded in-hospital complications (medical or neurosurgical), reoperations and in-hospital death, the primary outcome. Functional outcome was assessed at discharge with the modified Rankin Scale (mRS) [20], deaths coded 6; an mRS ≤ 2 was a good outcome. For unmet indications in ICH, the reason for non-fulfilment was recorded case by case from the medical file, as noted by the treating team. A single principal reason was retained per patient, so that the categories (financial obstacle, theatre unavailable, clinical deterioration before the procedure, preoperative death, family refusal, not documented) are mutually exclusive. This recording was not carried out for the other stroke subtypes. Haematoma volume and the ICH score [21], defined for ICH only, were compared in this subgroup.

2.4. Statistical analysis

Categorical variables are given as n (%), with the Wilson 95% CI for the main proportions; continuous variables as median [interquartile range, IQR]. Comparisons used the Mann-Whitney test (continuous variables) and Fisher's exact test (proportions), without correction for multiplicity, and are therefore exploratory.

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In-hospital mortality, then non-fulfilment of an indication in patients with an indication, were explored by logistic regression, univariable then multivariable. The covariates of the mortality model were chosen a priori on clinical and parsimony grounds, without selection based on univariable significance: age, Glasgow score and ventricular flooding (initial prognostic factors), and pathway (no indication [reference], surgery performed, unmet indication), the main exposure. Hydrocephalus (redundant with ventricular flooding), stroke subtype (structurally linked to the pathway; analysis excluding SAH as a sensitivity analysis) and haematoma volume (defined only in ICH, analysed in that subgroup: Table 6) were excluded a priori. The direct contrast between unmet indication and surgery was estimated with operated patients as the reference; in case of near-complete separation, we used Firth's penalised regression.

The mortality model had five terms for 53 deaths (about 10.6 events per term). Collinearity (maximum variance inflation factor 1.22), calibration (Hosmer-Lemeshow: $\chi^2 = 6.71$; $p = 0.568$) and discrimination (area under the ROC curve, AUC) were checked. The Glasgow score was missing in 31 of 250 patients (12.4%): complete-case analysis; these patients did not differ from the others in age ($p = 0.941$) or mortality (22.6% versus 24.2%; $p > 0.99$). A sensitivity analysis excluded from the unmet group the patients who died or deteriorated before theatre, to assess immortal time bias. Two-sided tests, 0.05 threshold; Python 3 (pandas, SciPy, statsmodels, scikit-learn).

2.5. Ethical considerations

Bouaké University Hospital did not have a constituted ethics committee during the study period (January 2022 to December 2023). Patients were enrolled and their data collected prospectively as part of routine care, after authorisation from the head of the neurosurgery department and the hospital management, in accordance with the principles of the Declaration of Helsinki; no other authorisation existed at the time of enrolment. Once constituted, the Institutional Ethics Committee of Bouaké University Hospital approved the analysis of these previously collected, anonymised routine-care data (approval no. CEI/CHU-BKE/130/2026). This approval covers the waiver of individual consent.

3. Results

3.1. Neurosurgical needs and fulfilment of indications

Of 250 patients, 107 (42.8%; 95% CI 36.8–49.0) had a neurosurgical indication, but fewer than half were operated on: 45 patients, or 18.0% of the cohort (95% CI 13.7–23.2). No one was operated on without an indication. Of the 107 indications, 45 were fulfilled (42.1%) and 62 were not (57.9%; 95% CI 48.5–66.9) (Figure 1).

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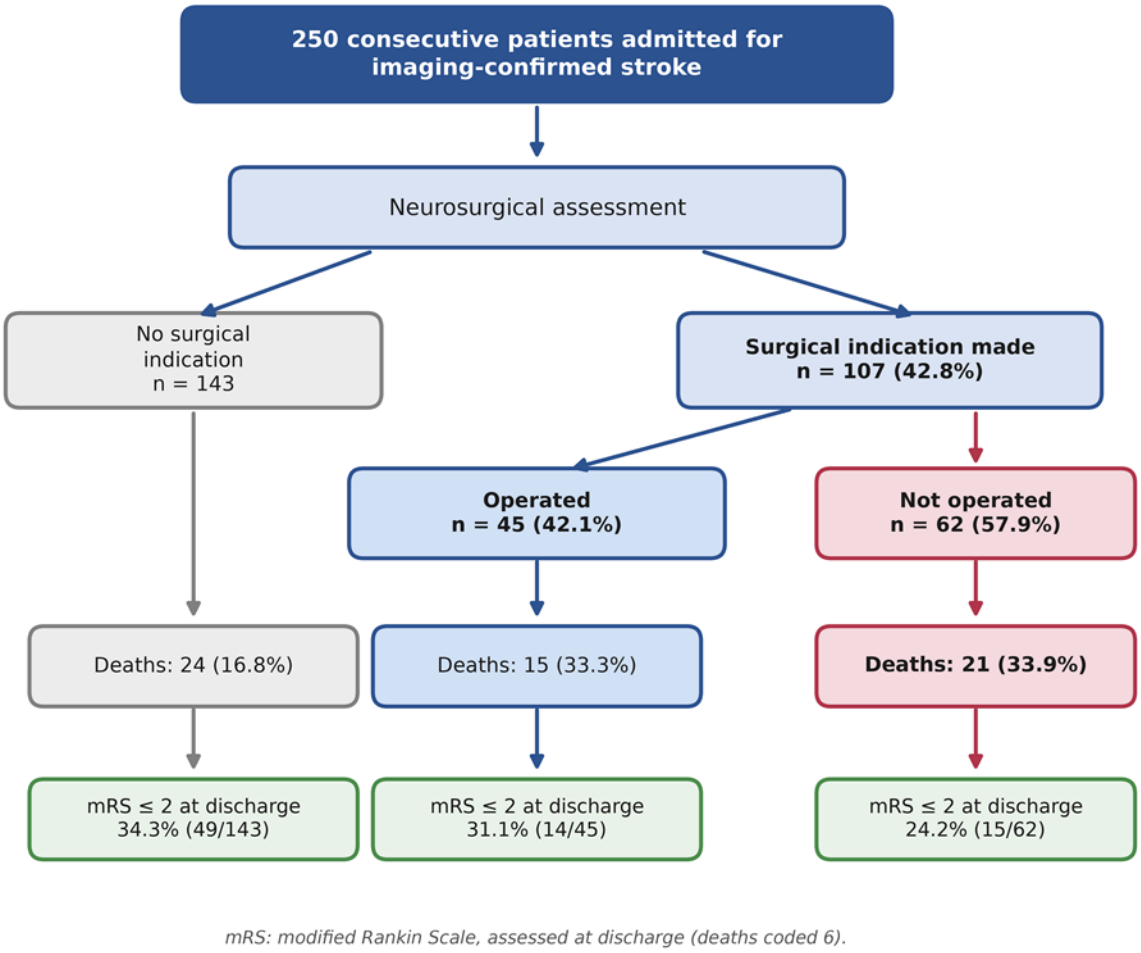


Figure 1: Neurosurgical decision pathway of stroke patients, from admission to in-hospital mortality and functional outcome at discharge, according to the existence of a surgical indication and its fulfilment. mRS: modified Rankin Scale.

The use of surgery varied by subtype (Table 2): 40/149 (26.8%) in ICH, 5/65 (7.7%) in ischaemic stroke, none in SAH (0/30) or cerebral venous thrombosis (0/6). No patient with SAH or an aneurysm received exclusion treatment.

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Table 2: Surgical indications, operation rates and in-hospital mortality by stroke subtype (n = 250). Percentages calculated by row.

Stroke subtype	n	Indication, n (%)	Operated, n (%)	Deaths, n (%)
Intracerebral haemorrhage	149	77 (51.7)	40 (26.8)	41 (27.5)
Ischaemic	65	14 (21.5)	5 (7.7)	7 (10.8)
Subarachnoid haemorrhage	30	15 (50.0)	0 (0.0)	12 (40.0)
Cerebral venous thrombosis	6	1 (16.7)	0 (0.0)	0 (0.0)
Total	**250**	**107 (42.8)**	**45 (18.0)**	**60 (24.0)**

3.2. Fulfilled or unmet indication: two groups of comparable severity

Among the 107 patients with an indication, operated (45) and non-operated (62) patients were similar: age, sex, time to admission, Glasgow score, hydrocephalus and ventricular flooding did not differ (Table 3). In ICH, where haematoma volume and ICH score are defined, operated (n = 40) and unmet (n = 37) patients were also comparable (volume 31.1 [20.5–42.6] versus 34.8 [25.0–46.1] mL, p = 0.617; ICH score 2 [1–2] in both groups, p = 0.459). Only hypertension (p = 0.011) and SAH (p < 0.001) differed, all 15 SAH being in the unmet group: the real difference was the subtype, an SAH never being operated on.

Despite the same surgical need and comparable severity, mortality was the same, 33.3% in operated patients and 33.9% with an unmet indication (p > 0.99), as was good functional outcome (mRS ≤ 2: 31.1% versus 24.2%; p = 0.510). Operated patients were nevertheless more severe at admission than all non-operated patients (median Glasgow 11 versus 12): the usual indication bias forbids reading a crude operated/non-operated comparison as an effect of surgery.

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Table 3: Comparison of patients with a fulfilled or unmet surgical indication (n = 107). Continuous variables: median [IQR] (Mann-Whitney); categorical: n (%) (Fisher's exact test). Haematoma volume and ICH score: calculated in intracerebral haemorrhage only. mRS: modified Rankin Scale, recorded at discharge (deaths coded 6).

Variable	Indication fulfilled (n = 45)	Unmet indication (n = 62)	p
Age (years), median [IQR]	55 [45–61]	56 [46–65]	0.360
Male sex, n (%)	28 (62.2%)	38 (61.3%)	>0.99
Time to admission (days), median [IQR]	2 [1–2]	2 [1–4]	0.364
Hypertension, n (%)	30 (66.7%)	25 (40.3%)	0.011
Glasgow score, median [IQR]	11 [7–13]	12 [8–14]	0.184
Haematoma volume (mL), ICH only (n = 40 / 37), median [IQR]	31.1 [20.5–42.6]	34.8 [25.0–46.1]	0.617
ICH score, ICH only (n = 40 / 37), median [IQR]	2 [1–2]	2 [1–2]	0.459
Subarachnoid haemorrhage, n (%)	0 (0.0%)	15 (24.2%)	<0.001
Hydrocephalus, n (%)	20 (44.4%)	24 (38.7%)	0.558
Ventricular flooding, n (%)	26 (57.8%)	33 (53.2%)	0.696
In-hospital death, n (%)	15 (33.3%)	21 (33.9%)	>0.99
Good functional outcome at discharge (mRS ≤ 2), n (%)	14 (31.1%)	15 (24.2%)	0.510

3.3. Reasons for non-fulfilment and death before theatre

The reason for non-fulfilment was recorded for the 37 unmet indications in ICH: financial obstacle (8 patients, 21.6%), theatre unavailable (8, 21.6%), clinical deterioration before the procedure (4, 10.8%), preoperative death (3, 8.1%), family refusal (4, 10.8%), not documented (10, 27.0%). A material obstacle therefore concerned 16 indications (43.2%) and the patient's condition 7 (18.9%). Outside ICH (15 SAH, 9 malignant infarctions, 1 cerebral venous thrombosis), the reasons were not recorded case by case, and we did not try to reconstruct them retrospectively, which would have introduced bias. For the 15 SAH, the absence of an aneurysm treatment pathway in the hospital is a structural explanation, not an individually documented reason; referral difficulties, clinical deterioration or treatment limitations may also have played a part.

These reasons change how mortality should be read. Seven patients in the unmet group, all in ICH, had deteriorated or died before reaching theatre (4 deteriorations, 3 preoperative deaths).

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Six died (85.7%), i.e. six of the ten deaths in unmet ICH; the other 30 indications of this subtype account for 4 (13.3%). Without them, the unmet group comprises 55 patients and 15 deaths (27.3%), a mortality that does not differ significantly from that of patients without an indication (24/143, 16.8%; p = 0.112) or of operated patients (15/45, 33.3%; p = 0.520). In the adjusted model without them (n = 214, 49 deaths), neither surgery (aOR 1.60 [0.65–3.91]; p = 0.302) nor unmet indication (aOR 1.81 [0.76–4.28]; p = 0.178) was significantly associated with mortality.

3.4. Procedures performed

The 45 operated patients underwent 54 procedures: 24 external ventricular drainages (EVD; 53.3% of operated patients), 24 decompressive craniectomies (53.3%) and 6 haematoma evacuations (13.3%). Nine patients (20.0%) had two procedures (6 drainages with craniectomy, 3 drainages with evacuation) (Figure 2, Table 4). The 40 patients operated for ICH had 49 procedures (24 drainages, 19 craniectomies, 6 evacuations); the 5 patients operated for malignant infarction all had a craniectomy. Three patients were returned to theatre. Only 3 intravenous thrombolyses were performed, all outside the 45 operated patients; neither thrombectomy, clipping nor embolisation was available.

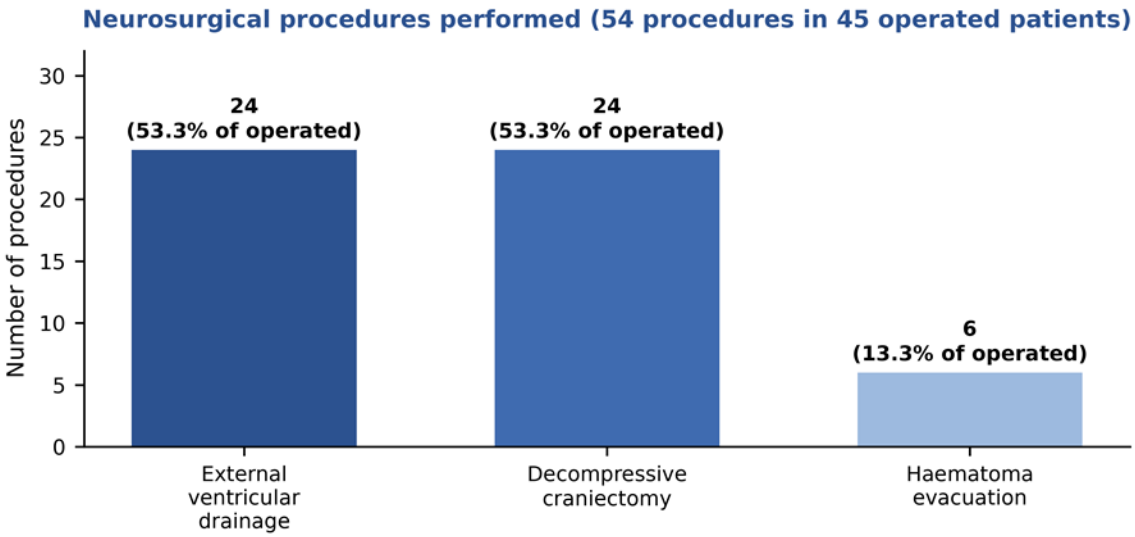


Figure 2: Distribution of the 54 neurosurgical procedures performed in the 45 operated patients (procedures not mutually exclusive). EVD: external ventricular drainage.

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Table 4: Interventions performed and associated mortality (45 operated patients). The 54 procedures are not mutually exclusive: 9 patients (20.0%) had two procedures (6 drainages with craniectomy, 3 drainages with evacuation), so that mortality per procedure counts these patients twice. Thrombolyses do not define operated status.

Intervention	n	% of operated	Deaths, n (%)
Neurosurgical procedures			
External ventricular drainage	24	53.3	10 (41.7)
Decompressive craniectomy	24	53.3	8 (33.3)
Haematoma evacuation	6	13.3	2 (33.3)
Reoperation	3	—	—
Reperfusion procedures			
Intravenous thrombolysis	3	—	—
Mechanical thrombectomy	0	—	—
Aneurysm treatment			
Clipping	0	—	—
Embolisation (coiling)	0	—	—

3.5. Complications

At least one complication occurred in 122 patients (48.8%), more often in operated patients (28; 62.2%) than in non-operated patients (94; 45.9%), borderline significant ($p = 0.050$). Only epileptic seizure differed (13.3% versus 4.9%; $p = 0.047$, without correction for multiple comparisons). The dominant complications were medical, related to prolonged bed rest (pneumonia, pressure ulcer, urinary tract infection); rebleeding and secondary hydrocephalus remained rare (Table 5). The excess in operated patients probably reflects their initial severity and longer stay.

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Table 5: In-hospital complications by surgical status, divided into medical and neurosurgical complications. Values are n (%); Fisher's exact test, without correction for multiple comparisons.

Complication	All (n = 250)	Operated (n = 45)	Non-operated (n = 205)	p
Medical complications				
Pneumonia	45 (18.0%)	11 (24.4%)	34 (16.6%)	0.283
Pressure ulcer	42 (16.8%)	8 (17.8%)	34 (16.6%)	0.828
Urinary tract infection	23 (9.2%)	7 (15.6%)	16 (7.8%)	0.149
Venous thrombosis	7 (2.8%)	2 (4.4%)	5 (2.4%)	0.613
Pulmonary embolism	5 (2.0%)	1 (2.2%)	4 (2.0%)	1.000
Neurosurgical complications				
Hydrocephalus (complication)	22 (8.8%)	4 (8.9%)	18 (8.8%)	1.000
Rebleeding	12 (4.8%)	3 (6.7%)	9 (4.4%)	0.457
Epileptic seizure	16 (6.4%)	6 (13.3%)	10 (4.9%)	0.047
Vasospasm	6 (2.4%)	0 (0.0%)	6 (2.9%)	0.595
At least one complication	**122 (48.8%)**	**28 (62.2%)**	**94 (45.9%)**	**0.050**

3.6. Mortality and associated factors

Overall in-hospital mortality was 24.0% (60/250; 95% CI 19.1–29.7): 16.8% without indication, 33.3% in operated patients, 33.9% with an unmet indication (Figure 3; mortality by procedure: Table 4). By subtype, mortality of unmet indications was 27.0% in ICH (10/37), 22.2% in malignant infarction (2/9) and 60.0% in SAH (9/15), versus 23.6% (17/72), 7.8% (4/51) and 20.0% (3/15) without indication. Patients operated for ICH had a mortality of 35.0% (14/40); only one of the 5 patients operated for malignant infarction died. In SAH, the gap (60.0% versus 20.0%) does not reach significance ($p = 0.060$, Fisher's exact test).

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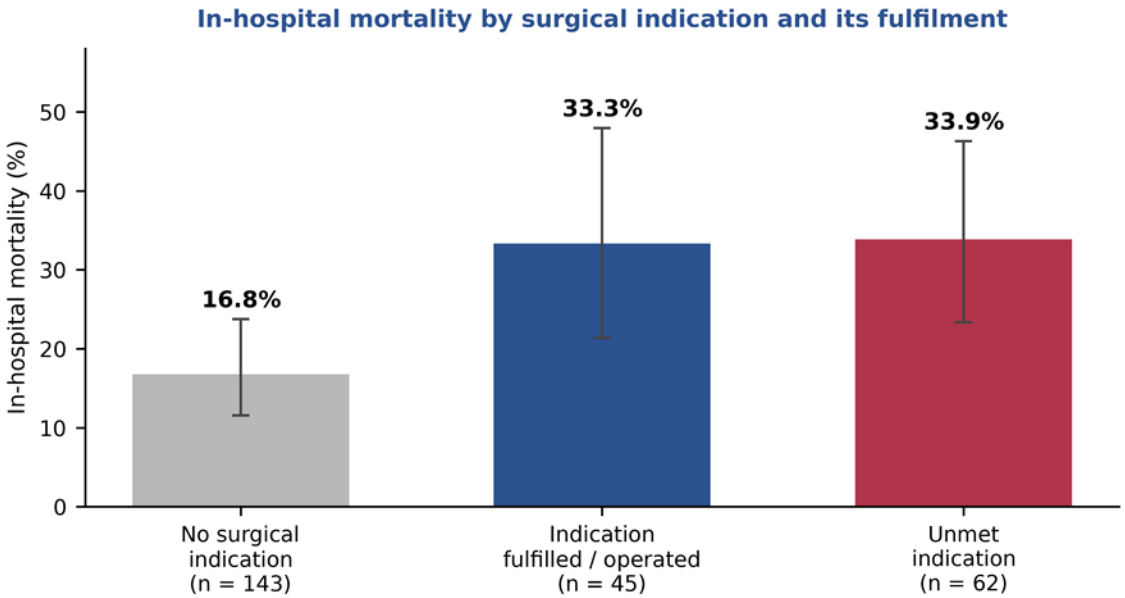


Figure 3: In-hospital mortality by surgical indication and its fulfilment (error bars: Wilson 95% CI).

On univariable analysis (Table 6), mortality was associated with Glasgow score (OR 0.68 per point; $p < 0.001$), hydrocephalus (OR 3.85), ventricular flooding (OR 3.84), stroke subtype ($p = 0.004$), haematoma volume in ICH (OR 1.39 per 10 mL; $p = 0.025$), surgery (OR 2.48; $p = 0.019$) and unmet indication (OR 2.54; $p = 0.008$), the last two relative to no indication. Age, sex and hypertension were not related to it.

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Table 6: Univariable associations with in-hospital mortality (crude odds ratios, on available cases for each variable). Haematoma volume: intracerebral haemorrhage only. Reference for the pathway: patients without a surgical indication.

Variable	Crude OR (95% CI)	p
Age (per year)	0.99 (0.97–1.02)	0.659
Male sex	1.26 (0.69–2.29)	0.455
Hypertension	1.29 (0.72–2.31)	0.400
Glasgow score (per point)	0.68 (0.58–0.79)	<0.001
Hydrocephalus	3.85 (2.10–7.06)	<0.001
Ventricular flooding	3.84 (2.09–7.05)	<0.001
Stroke subtype (global test)	—	0.004
Haematoma volume, ICH only (per 10 mL)	1.39 (1.04–1.84)	0.025
Surgery performed (vs no indication)	2.48 (1.16–5.30)	0.019
Unmet indication (vs no indication)	2.54 (1.28–5.04)	0.008

On multivariable analysis (Table 7, Figure 4; n = 219, 53 deaths; AUC 0.78), two factors emerged: a low Glasgow score (aOR 0.76 (0.68–0.85) per point; $p < 0.001$) and ventricular flooding (aOR 2.29 (1.09–4.79); $p = 0.028$). After adjustment for severity, unmet indication remained associated with a higher risk of death than no indication, without reaching significance (aOR 2.10 (0.92–4.78); $p = 0.077$), and surgery was not (aOR 1.60 (0.65–3.91); $p = 0.304$). With operated patients as the reference, unmet indication gave an aOR of 1.31 (0.49–3.50; $p = 0.587$): the two situations cannot be distinguished in our sample. As the unmet group contains patients who died or deteriorated before theatre (section 3.3), this association should not be read as the effect of the absence of a procedure.

Table 7: Factors associated with in-hospital mortality (multivariable logistic regression, complete cases n = 219, 53 deaths; AUC 0.78; Hosmer-Lemeshow p = 0.568). Reference for the pathway: patients without a surgical indication.

Variable	aOR (95% CI)	p
Age (per year)	1.00 (0.98–1.03)	0.762
Glasgow score (per point)	0.76 (0.68–0.85)	<0.001
Ventricular flooding	2.29 (1.09–4.79)	0.028
Surgery performed (vs no indication)	1.60 (0.65–3.91)	0.304
Unmet indication (vs no indication)	2.10 (0.92–4.78)	0.077

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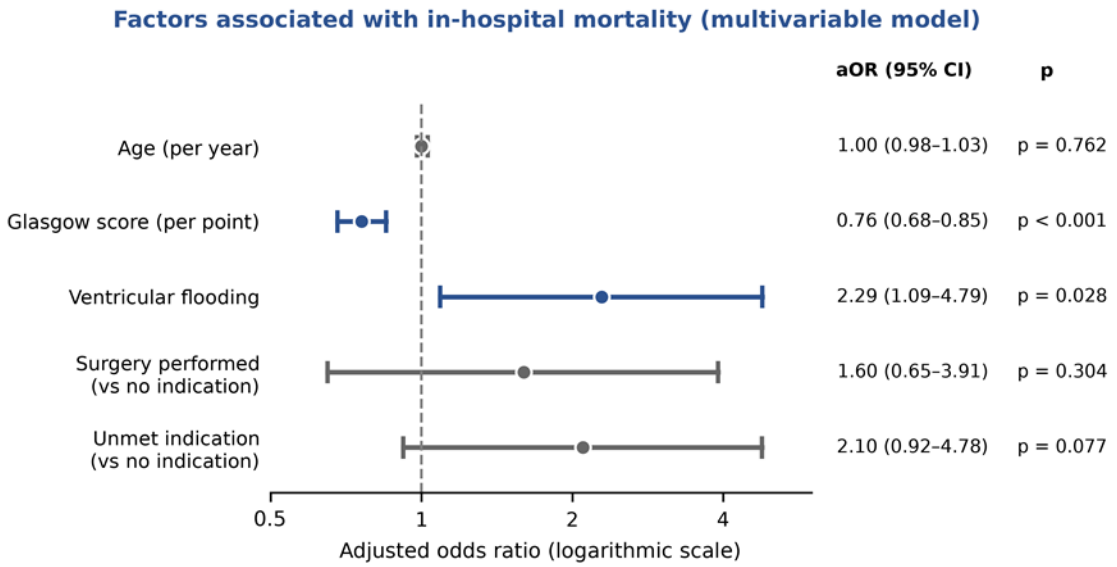


Figure 4: Adjusted odds ratios of the factors associated with in-hospital mortality (multivariable model; bars: 95% CI).

No patient-related factor (age, sex, neurological severity) was associated with non-fulfilment of an indication (Table 8; Firth regression, n = 91). Only SAH emerged (aOR 23.48 (1.31–421.57); p = 0.032), which most likely reflects the absence of an aneurysm pathway rather than a patient characteristic; the very wide interval, due to separation (no SAH operated on), requires an exploratory reading.

Table 8: Factors associated with non-fulfilment of an indication among the 107 patients with an indication (Firth regression, n = 91). The estimate for SAH is unstable (small numbers, separation: no SAH operated on) and exploratory.

Variable	aOR (95% CI)	p
Age (per year)	1.02 (0.99–1.06)	0.201
Male sex	0.58 (0.23–1.48)	0.252
Glasgow score (per point)	1.07 (0.93–1.24)	0.347
Subarachnoid haemorrhage	23.48 (1.31–421.57)	0.032

These results held in sensitivity analyses. Excluding SAH, no patient-related factor (age, sex, Glasgow score, time to admission) was associated with non-fulfilment (all p > 0.15; n = 76), which argues for obstacles external to the initial clinical profile, without excluding deterioration before the procedure (section 3.3). Still excluding SAH (n = 193), neither unmet indication (aOR

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1.74 (0.68–4.44); p = 0.248) nor surgery (aOR 1.57 (0.61–4.01); p = 0.349) was significantly associated with mortality.

3.7. Functional outcome at discharge

Overall, 78 patients (31.2%; 95% CI 25.8–37.2) had a good functional outcome (mRS ≤ 2) at discharge; 172 (68.8%) had an mRS > 2, deaths being coded 6. This rate varied little by pathway (Figure 5): 34.3% (49/143; 95% CI 27.0–42.4) without indication, 31.1% (14/45; 95% CI 19.5–45.7) in operated patients, 24.2% (15/62; 95% CI 15.2–36.2) with an unmet indication, with no significant difference (unmet indication versus no indication, p = 0.190; versus surgery, p = 0.510; surgery versus no indication, p = 0.856). Operated patients, more severe at admission, reached a comparable outcome: without an adjusted comparison, no benefit of surgery can be inferred.

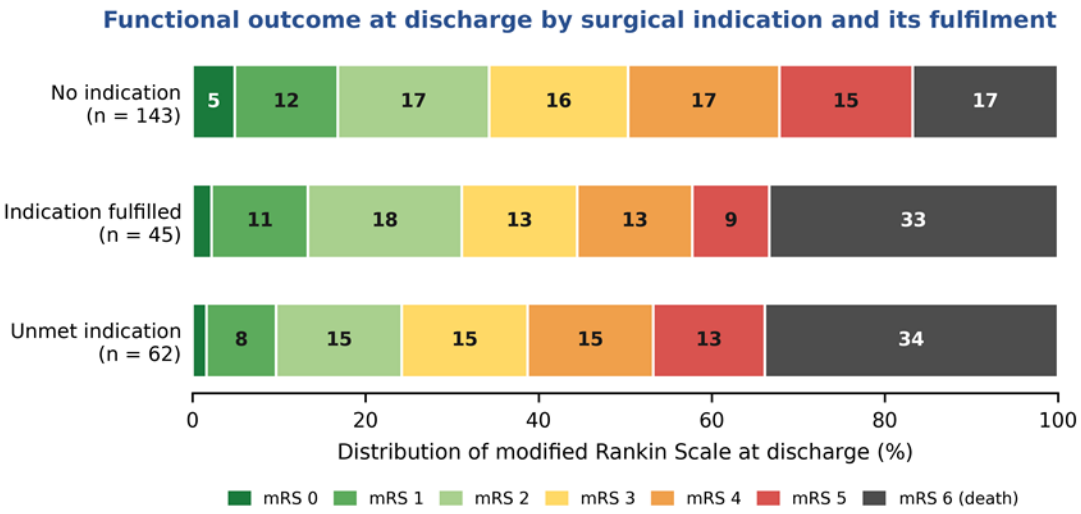


Figure 5: Distribution of the modified Rankin Scale score at discharge by surgical indication and its fulfilment.

4. Discussion

In this Ivorian cohort, more than four patients in ten had a surgical indication, but fewer than one indication in two could be fulfilled. The higher mortality of patients whose indication was not honoured, compared with that of patients without an indication, cannot be put down to the absence of a procedure. Together with the analysis of the same cohort that preceded it [17], this is to our knowledge one of the first prospective studies in the region to describe the neurosurgical pathway of stroke, from indication to hospital outcome: it measures unmet needs in a referral centre in West Africa.

4.1. An operation rate constrained by access, not by indications

An operation rate of 18.0% for 42.8% of indications: the gap points to a supply constraint rather than a reserve of indication, although the documented reasons, available only in ICH, account for only part of it (section 4.2). In high-income centres, the debate concerns the very value of ICH surgery, since STICH and STICH II showed no overall advantage of early evacuation [12,13] and minimally invasive techniques benefit only subgroups [14,15]. Here, the first question is not "should we operate?" but "can we operate on those who should be?".

4.2. Why so many unmet indications?

Nearly six indications in ten were not fulfilled. Neither age, sex nor initial severity explained it; only SAH emerged, which points to a structural gap rather than a patient characteristic. For the 37 unmet indications in ICH, a reason was documented in 27: a material obstacle in 16 (8 financial, 8 theatre unavailable), deterioration or death before the procedure in 7, and family refusal in 4; no reason was documented in the remaining 10. Access is therefore the main documented reason, but the documented barriers account for 27 of the 37 cases, not for all of them, and they cannot be extrapolated to the 10 cases without a documented reason or to the 25 unmet indications outside ICH, for which no reason was recorded. As a single principal reason was retained per patient, the categories do not overlap, and lifting only one of the two material obstacles would resolve only half of the documented material barriers.

4.3. Neurovascular surgery: a major gap

No clipping or embolisation in the 30 patients with SAH, no thrombectomy: the neurovascular pathway is absent. SAH mortality reached 40.0%, the highest of all subtypes. Without interventional angiography or routine vascular microsurgery, these patients received only medical treatment. We interpret this as the consequence of a missing technical platform rather than a therapeutic choice; this explanation is ours, since the individual reason for non-fulfilment was not recorded outside ICH. A neurovascular capacity, even limited to exclusion microsurgery and built with national and international collaborations, would be a major step forward [4,22].

4.4. Prognostic consequences

Patients whose indication was not fulfilled had a crude mortality close to that of operated patients and roughly double that of patients without an indication. After adjustment for severity, the association remains non-significant (aOR 2.10; 95% CI 0.92–4.78; p = 0.077), as does the direct contrast with operated patients (aOR 1.31; 0.49–3.50). Several elements preclude reading a loss of chance into it. The composition of the group matters: in ICH, mortality of unmet indications is close to that of patients without an indication (27.0% versus 23.6%); it is higher in SAH (60.0% versus 20.0%; p = 0.060), whose 15 indications all went unanswered, most probably for lack of an aneurysm pathway.

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Seven patients, all in ICH, died or deteriorated before reaching theatre: six died, i.e. six of the ten deaths in this subgroup, versus 4 deaths (13.3%) among the other 30 unmet ICH indications. Without them, the crude mortality of the group falls from 33.9% to 27.3% (15/55), with no significant difference from patients without an indication (16.8%; p = 0.112) or from operated patients (33.3%; p = 0.520), and the aOR falls to 1.81 (0.76–4.28). A patient who dies before the procedure is classified as "unmet" by construction: this is immortal time bias. Operated patients, for their part, are selected on their condition and their accessibility to surgery, hence an indication bias.

Our study therefore measures the gap between indication and fulfilment, not its consequences for survival. These require a dedicated analysis, with the delay between indication and procedure as exposure time, a delay that our database does not provide reliably.

4.5. Complications that are first and foremost medical

Pneumonia, pressure ulcer, urinary tract infection: this is the profile of a severe neurological illness in a bedridden patient, not that of a risky operation. The excess in operated patients is explained by their severity and length of stay. Supportive care (nursing, pressure ulcer prevention, respiratory physiotherapy, thromboembolism prevention) is an accessible and inexpensive lever.

4.6. A "Global Neurosurgery" reading

Beyond stroke, these results belong to global neurosurgery. The Lancet Commission on Global Surgery showed that the deficit in surgical care is greatest in sub-Saharan Africa, where low operative volumes are accompanied by high case fatality for treatable conditions and where the cost of care exposes families to catastrophic expenditure [23]; neurosurgery is particularly affected, with a major shortage of neurosurgeons and infrastructure [24]. The gap we describe between indications made and procedures performed (the neurosurgical treatment gap [25]) thus measures the capacity of a system to deliver interventions already recognised as necessary, not mere activity. Figure 6 summarises the pathway and the obstacles that interrupt it.

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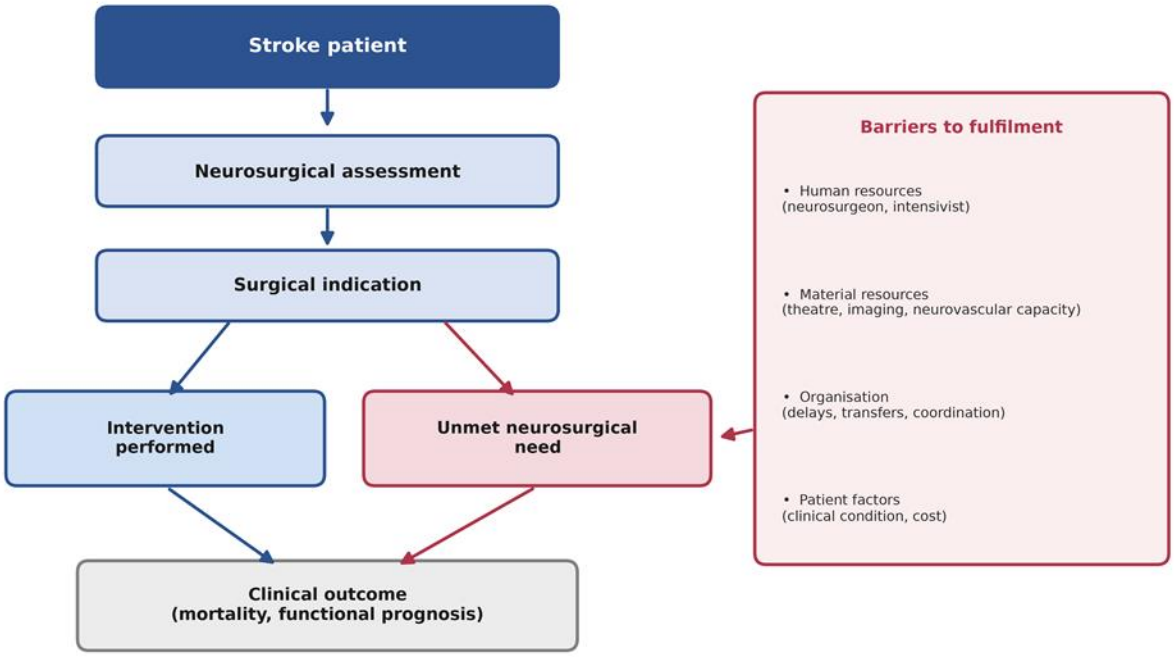


Figure 6: Conceptual model of the neurosurgical pathway in stroke and of the obstacles to fulfilling surgical indications in a resource-limited setting.

We propose, as a working hypothesis, a simple indicator: the neurosurgical indication fulfilment rate, the ratio of procedures performed to indications made (here 42.1%). It is reproducible, comparable between centres, and could complement the classical indicators of mortality and complications. We do not present it as validated: its relevance, limits and thresholds remain to be assessed in multicentre cohorts before any use for health system monitoring.

4.7. Comparison with the African literature

Our results are in line with West African data reporting high in-hospital case fatality in stroke and ICH, notably the SIREN studies in Ghana and Nigeria and regional hospital series [3,6,26–28]. Our contribution, after [17], is to study the reasons for non-fulfilment of indications and their relation to mortality, and not only the outcome of operated patients.

4.8. Practical implications

Short term: identify indications early, speed up decision-making and transfers, coordinate teams, secure financial access to neurosurgical emergencies. Medium term: guarantee the permanent availability of theatre, equipment and neurocritical care. Long term: develop vascular neurosurgery and interventional neuroradiology, and strengthen specialist training. These axes

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echo regional priorities for stroke care in Africa [3,4,22,28]: neurosurgical results depend as much on the organisation of care as on technical skills.

4.9. Limitations and strengths

Our study is single-centre and reflects the organisation of a single department, which limits its external validity, even though the difficulties of Bouaké are probably shared by many centres in sub-Saharan Africa. It is observational: crude operated/non-operated comparisons are not to be read as a causal effect of surgery, and we do not seek to establish one.

The main limitation is the absence of standardised coding of the reasons for non-fulfilment: they were recorded only for the 37 unmet indications in ICH (of which 10 without a usable reason), not for the other 25. Across all 62, we therefore cannot separate structural constraints from rapidly unfavourable courses, and immortal time bias is handled only by excluding patients who died or deteriorated before theatre. The documented reasons therefore describe 27 of the 62 unmet indications. Prospective, standardised collection of these causes for all subtypes is the priority.

The classification of patients into fulfilled and unmet indications, central to this study, rests on an indication made by the neurosurgeon on call, with a second opinion only in complex situations, without a written protocol, predefined numerical thresholds or a formalised multidisciplinary meeting. The indications were not reviewed by an independent neurosurgeon and interobserver agreement was not measured. Patients with similar presentations may therefore have been assessed differently, and some misclassification between the three pathways cannot be excluded; its direction is unknown.

Other limitations: delay between indication and procedure not reliable; haematoma location missing for almost all ICH; functional outcome recorded only at discharge, without quality of life or health-economic data. The mortality model contains, by a priori choice, neither hydrocephalus, nor stroke subtype, nor haematoma volume, although they are related to mortality on univariable analysis (Table 6): adjustment covers age, Glasgow score and ventricular flooding, which its 53 events also imposed. Complication comparisons are not corrected for multiplicity. The multivariable models, in particular the Firth model for SAH, rest on few events: they are exploratory, subject to residual confounding.

The strengths are prospective data collection, the consecutive cohort, the low proportion of missing data and a detailed description of the pathway, from indication to fulfilment, in a poorly documented setting.

5. Conclusion

In this Ivorian cohort, the main limit of neurosurgery for stroke was not identifying indications but honouring them: an indication was made in 42.8% of patients, followed by a procedure in

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only 42.1% of cases. Among the reasons documented in ICH, access (money, theatre availability) was the most frequent, but these documented reasons cover only 27 of the 37 unmet indications in this subtype. The excess mortality of patients whose indication was not fulfilled cannot be attributed to the absence of a procedure until the patients who died or deteriorated before theatre have been the subject of a dedicated analysis. Reducing the gap between indication and intervention remains the most directly actionable avenue in resource-limited countries.

6. Declarations

Ethics approval. Bouaké University Hospital did not have a constituted ethics committee during the study period; patients were enrolled and data collected prospectively as part of routine care, after authorisation from the head of the neurosurgery department and the hospital management, in accordance with the principles of the Declaration of Helsinki. The Institutional Ethics Committee of Bouaké University Hospital, constituted afterwards, approved the analysis of these anonymised data (approval no. CEI/CHU-BKE/130/2026).

Consent. Data were collected as part of routine care and analysed anonymously; the waiver of individual consent is covered by the approval of the institutional ethics committee.

Consent for publication. The manuscript contains no data, image or clinical detail allowing a patient to be identified. Data were analysed in anonymised form, under the conditions described in section 2.5.

Related publications. The overall numbers of indications, operated patients and procedures of this cohort were reported in [17], an article devoted to predicting the indication; they are cited here, not reanalysed. The analyses presented in this article (fulfilment of indications, reasons for non-fulfilment, mortality, functional outcome, complications and factors associated with non-fulfilment) are new. Other manuscripts drawn from the same cohort, submitted or in preparation, address distinct questions: surgery versus conservative treatment in intracerebral haemorrhage, functional prognosis, admission delay and mortality, and stroke in young adults. The present article reuses none of their results.

Data availability. The data may be obtained from the corresponding author on reasonable request, subject to the regulations applicable to the protection of health data.

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Conflicts of interest. The authors declare no conflicts of interest.

Author contributions. All authors contributed to the study design, data collection and analysis, drafting and critical revision of the manuscript; all approved the submitted version and take responsibility for it.

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