

What Leads to Operating on a Spontaneous Intracerebral Haemorrhage: Secondary Analysis of a Prospective Cohort of 149 Patients at Bouaké University Hospital (Côte d'Ivoire)

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ABSTRACT: Background. Whether to operate on a spontaneous intracerebral haemorrhage (ICH) is still debated, and the choice rests largely on the team's judgement. Little is known about the criteria that actually tip the balance, especially where resources are limited. We looked at what leads neurosurgeons to recommend surgery, not at whether surgery works. Methods. We analysed 149 consecutive patients with spontaneous ICH from a prospective cohort of 250 strokes managed in the neurosurgery department of Bouaké University Hospital from 1 January 2022 to 31 December 2023. The outcome was the surgical indication recorded in the chart. Six factors were tested by logistic regression: age, Glasgow Coma Scale (GCS), haematoma volume, mass effect, intraventricular haemorrhage and hydrocephalus. The main model used the 127 patients with complete data. Haematoma location, almost never recorded, could not be studied. We assessed discrimination (AUC), calibration (Hosmer-Lemeshow test) and collinearity (VIF), then checked robustness by multiple imputation and in the whole cohort with a known GCS (n = 219). Results. A surgical indication was made in 77 patients (51.7%): 40 were operated on and 37 were not. Three factors remained associated with the indication after adjustment: mass effect (adjusted odds ratio [aOR] 3.19; 95% CI 1.33–7.63; p = 0.009), hydrocephalus (aOR 3.70; 95% CI 1.31–10.49; p = 0.014) and intraventricular haemorrhage (aOR 2.42; 95% CI 1.04–5.63; p = 0.041). Age (aOR 0.93 per 10 years; p = 0.59), GCS (aOR 0.91 per point; p = 0.20) and haematoma volume (aOR 0.88 per 10 mL; p = 0.32) were not. Discrimination was moderate (apparent AUC 0.76; 0.72 after bootstrap correction) and calibration satisfactory (Hosmer-Lemeshow p = 0.55; VIF < 1.4). After multiple imputation, mass effect (aOR 3.06) and hydrocephalus (aOR 5.02) remained significant. Intraventricular haemorrhage kept the same direction without reaching significance (aOR 1.96; 95% CI 0.90–4.28; p = 0.091). In the 219 patients with a known GCS, all three signs remained significant (AUC 0.75). Conclusion. In this Ivorian cohort, the decision to operate follows the signs of mechanical impact of the bleed — mass effect, hydrocephalus and intraventricular haemorrhage — more than haematoma volume, GCS or age. These findings show how the decision is made in practice when resources are limited.

KEYWORDS: intracerebral haemorrhage; surgical indication; mass effect; hydrocephalus; intraventricular haemorrhage; neurosurgery; sub-Saharan Africa; Côte d'Ivoire.

I. INTRODUCTION

Spontaneous intracerebral haemorrhage (ICH) is the most severe and deadliest form of stroke. It predominates in sub-Saharan Africa, where hypertension is poorly controlled and strokes occur early [1]–[5]. It is also the form that concentrates most neurosurgical indications: mass effect, herniation, intraventricular haemorrhage and acute hydrocephalus can threaten life in the short term [6] [7].

Should we operate? This is one of the most debated questions in vascular neurosurgery. The large trials of evacuation by open craniotomy (STICH, STICH II) showed no overall functional benefit [8] [9]. Minimally invasive techniques (MISTIE III), early parafascicular evacuation (ENRICH) and decompressive craniectomy in severe deep haematomas (SWITCH) have qualified this finding. Their results depend on location, volume and timing [10]–[12]. The debate has therefore shifted: the question is less whether to operate than whom to operate on. The guidelines leave a wide place for individual judgement, based on the patient's level of consciousness, the volume and location of the haematoma, and its effects on the brain [7] [13].

In practice, the team weighs several clinical and radiological elements, often without stating them. This reasoning is poorly documented, especially where the operating theatre, intensive care and follow-up imaging are hard to access. Making it visible has two benefits: comparing a centre's practice with reference standards, and teaching it.

Most studies look for what predicts death or disability after ICH. Very few address what leads to the indication. These are not the same question: what guides the decision is not necessarily what determines prognosis. We hypothesised that, in our centre, signs of mechanical impact weigh more heavily than the usual figures (volume, Glasgow score, age).

What Leads to Operating on a Spontaneous Intracerebral Haemorrhage: Secondary Analysis of a Prospective Cohort of 149 Patients at Bouaké University Hospital (Côte d'Ivoire)

We therefore looked, in a prospective cohort of spontaneous ICH managed in neurosurgery, for the clinical and radiological factors associated with the decision to operate: age, Glasgow score, haematoma volume, location, mass effect, intraventricular haemorrhage and hydrocephalus. We do not assess the effectiveness of surgery. This work complements a study already published on the same cohort of 250 strokes, which built a nomogram of the surgical indication for all stroke types combined [14]. It differs from it on three points: it is restricted to haemorrhages, it treats the Glasgow score and volume as continuous variables, and it discusses the place of volume relative to its mechanical consequences. It is part of a series of analyses derived from this cohort.

II. METHODS

A. Study Type and Setting

This is a secondary analysis of a prospective cohort, carried out in the neurosurgery department of Bouaké University Hospital, the referral hospital for central Côte d'Ivoire. It covers the period from 1 January 2022 to 31 December 2023; individual dates were checked in the database. The report follows the STROBE recommendations [15].

B. Participants

The source cohort comprised 250 consecutive patients aged 18 years or older, admitted for a stroke confirmed by CT or MRI. We excluded traumatic or tumoural haemorrhages and cases without imaging. This analysis covers the 149 patients with spontaneous ICH, the only situation in which the radiological signs studied have clinical meaning. Figure 1 shows the selection.

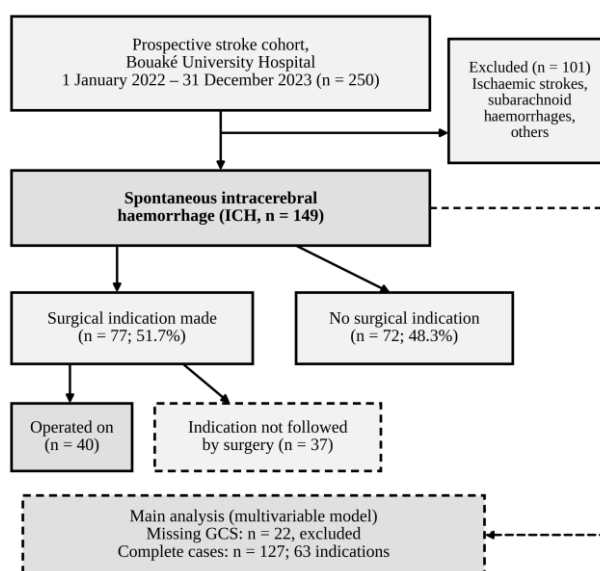


Figure 1. Selection of patients, surgical indication, performance of the procedure and sample size of the multivariable model (complete cases).

C. Outcome and Variables

The outcome was the surgical indication recorded in the chart (indication made or not). The neurosurgeon on call first assessed it, based on the clinical findings and the available imaging. He or she then discussed it with a second neurosurgeon when the situation was complex or when several options were available. We distinguish the indication from its performance: the procedure may be prevented by the limits of the technical facilities.

Six factors were prespecified: age, Glasgow Coma Scale (GCS) score on admission, haematoma volume (ABC/2 method [16]), mass effect, intraventricular haemorrhage and hydrocephalus. The three radiological signs were coded present or absent on the first CT scan. Mass effect corresponded to a midline shift, a compression of the ventricles or an effacement of the basal cisterns. Intraventricular haemorrhage corresponded to blood in one or more ventricles, and hydrocephalus to a ventricular dilatation. These data came from the reading of scans performed during care: there was no central re-reading and no measurement of inter-observer agreement. We had also planned haematoma location, but it was recorded in only one chart out of 149: we excluded it. Brain herniation (in millimetres) was described separately. A data quality check preceded the analysis.

D. Statistical Analysis

Quantitative variables are given as mean $\pm$ standard deviation and median [IQR]; qualitative variables as counts and percentages. To compare patients with and without an indication, we used the Mann-Whitney test, the χ^2 test or Fisher's exact test. We first estimated crude odds ratios by simple logistic regression (95% CI). The six factors were then entered together in a multivariable

What Leads to Operating on a Spontaneous Intracerebral Haemorrhage: Secondary Analysis of a Prospective Cohort of 149 Patients at Bouaké University Hospital (Côte d'Ivoire)

model. They had been chosen in advance for their clinical interest, whatever their significance in univariate analysis, with at least ten events per variable to limit overfitting.

The main model covered complete cases ($n = 127$; 63 indications). Among the 149 patients, 22 (14.8%) had no Glasgow score; this was the only clearly incomplete variable. We judged this absence plausibly random, because the complete-case analysis and multiple imputation agreed for mass effect and hydrocephalus. We checked collinearity (variance inflation factor, VIF) and the linearity of continuous variables (quadratic terms). Discrimination was measured by the AUC, calibration by the Hosmer-Lemeshow test and the Brier score. Model optimism was estimated by bootstrap (1,000 resamples, Harrell's method), which gives a corrected AUC.

Two sensitivity analyses were planned: multiple imputation by chained equations (20 imputations, $n = 149$) and an analysis of the whole stroke cohort with a known Glasgow score ($n = 219$). Age and volume are expressed in steps of 10 units so that the odds ratios remain readable. The significance threshold was set at $p < 0.05$. Analyses were performed with Python 3.12 (Statsmodels, SciPy, scikit-learn).

III. RESULTS

A. Population and Surgical Indication

Of the 149 patients with spontaneous ICH, a surgical indication was made in 77 (51.7%) and not in 72 (48.3%) (Figure 1). Of the 77 patients concerned, 40 (51.9%) were operated on: decompressive craniectomy, haematoma evacuation or external ventricular drain. The other 37 (48.1%) could not be. The gap between what was indicated and what was done is therefore considerable.

Age (53.7 ± 12.8 years with indication, 54.7 ± 16.1 without; $p = 0.70$) and haematoma volume (40.9 ± 17.3 mL versus 37.6 ± 18.4 mL; $p = 0.26$) were comparable in the two groups. The Glasgow score was slightly lower in patients with an indication (10.1 ± 3.2 versus 11.2 ± 2.9 ; $p = 0.06$), borderline for significance. The three signs of mechanical impact, for their part, differed clearly and were all more frequent when an indication was made: mass effect (76.6% versus 51.4%; $p = 0.002$), intraventricular haemorrhage (63.6% versus 33.3%; $p < 0.001$) and hydrocephalus (39.0% versus 9.7%; $p < 0.001$). Herniation was more marked (mean 6.0 versus 2.9 mm; median 6 versus 0 mm; $p < 0.001$) (Table I, Figure 2).

TABLE I CLINICAL AND RADIOLOGICAL CHARACTERISTICS ACCORDING TO SURGICAL INDICATION (N = 149)

Variable	Indication made (n = 77)	No indication (n = 72)	p
Age (years)	53.7 ± 12.8 (55 [45–61])	54.7 ± 16.1 (55 [45–67])	0.695
Glasgow Coma Scale	10.1 ± 3.2 (11 [7–13])	11.2 ± 2.9 (12 [10–13])	0.059
Haematoma volume (mL)	40.9 ± 17.3 (42 [30–52])	37.6 ± 18.4 (40 [25–48])	0.260
Herniation (mm)	6.0 ± 8.6 (6 [2–8])	2.9 ± 3.3 (0 [0–6])	<0.001
Mass effect, n (%)	59 (76.6)	37 (51.4)	0.002
Intraventricular haemorrhage, n (%)	49 (63.6)	24 (33.3)	<0.001
Hydrocephalus, n (%)	30 (39.0)	7 (9.7)	<0.001

Continuous variables: mean $\pm$ standard deviation (median [Q1–Q3]); Mann-Whitney test. Categorical variables: n (%); χ^2 or Fisher's exact test.

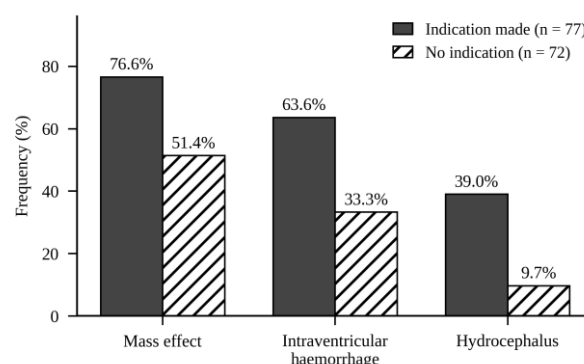


Figure 2. Frequency of the three signs of mechanical impact according to whether the surgical indication was made or not.

B. Univariate Analysis

In simple logistic regression, three signs were strongly associated with the indication: hydrocephalus (OR 5.93; 95% CI 2.40–14.64; $p < 0.001$), intraventricular haemorrhage (OR 3.50; 95% CI 1.78–6.87; $p < 0.001$) and mass effect (OR 3.10; 95% CI 1.54–6.25; p

= 0.002). The Glasgow score was borderline (OR 0.89 per point; 95% CI 0.79–1.00; $p = 0.050$, i.e. an OR of 1.12 per point lost). Age (OR 0.95 per 10 years; $p = 0.68$) and haematoma volume (OR 1.11 per 10 mL; $p = 0.26$) did not reach the threshold (Table II).

TABLE II SIMPLE LOGISTIC REGRESSION — ASSOCIATION WITH SURGICAL INDICATION

Variable	Crude OR	95% CI	p
Age (per 10 years)	0.95	0.76–1.19	0.682
Glasgow Coma Scale (per point)	0.89	0.79–1.00	0.050
Haematoma volume (per 10 mL)	1.11	0.93–1.33	0.258
Mass effect	3.10	1.54–6.25	0.002
Intraventricular haemorrhage	3.50	1.78–6.87	<0.001
Hydrocephalus	5.93	2.40–14.64	<0.001

OR: crude odds ratio. Analysis on available cases for each variable ($n = 127$ to 149).

C. Multivariable Analysis

The multivariable model on complete cases ($n = 127$; 63 indications; 10.5 events per variable) retained three independent factors: mass effect (aOR 3.19; 95% CI 1.33–7.63; $p = 0.009$), hydrocephalus (aOR 3.70; 95% CI 1.31–10.49; $p = 0.014$) and intraventricular haemorrhage (aOR 2.42; 95% CI 1.04–5.63; $p = 0.041$). After adjustment, age (aOR 0.93 per 10 years; $p = 0.59$), GCS (aOR 0.91 per point; $p = 0.20$) and volume (aOR 0.88 per 10 mL; $p = 0.32$) were no longer linked to the decision (Table III, Figure 3). Discrimination was moderate (apparent AUC 0.76; bootstrap-corrected AUC 0.72, optimism 0.043; Figure 4). Calibration was satisfactory (Hosmer-Lemeshow $p = 0.55$; Brier score 0.199, i.e. a gain in accuracy of about 20% over the null model; Figure 5). We found no collinearity ($VIF < 1.4$) and the linearity of the continuous variables was acceptable (quadratic terms not significant, $p \geq 0.05$).

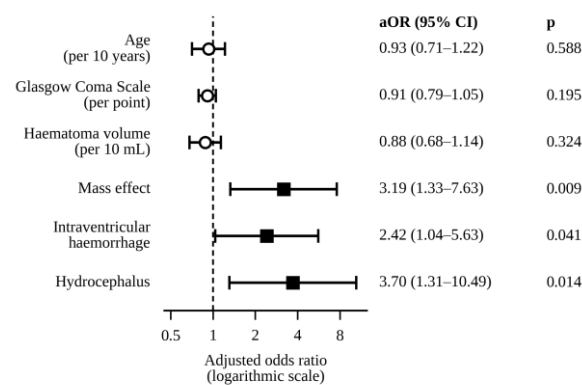


Figure 3. Factors independently associated with the surgical indication after adjustment (adjusted odds ratios, 95% CI). Filled squares mark the significant factors ($p < 0.05$).

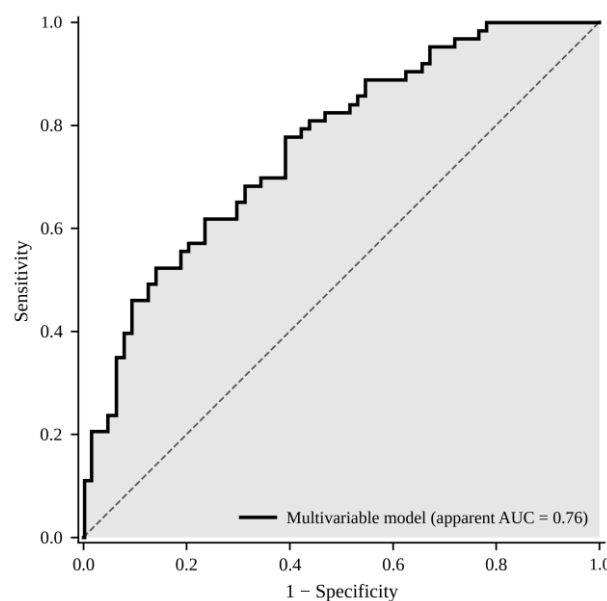


Figure 4. ROC curve of the multivariable model (apparent AUC 0.76; bootstrap-corrected 0.72).

What Leads to Operating on a Spontaneous Intracerebral Haemorrhage: Secondary Analysis of a Prospective Cohort of 149 Patients at Bouaké University Hospital (Côte d'Ivoire)

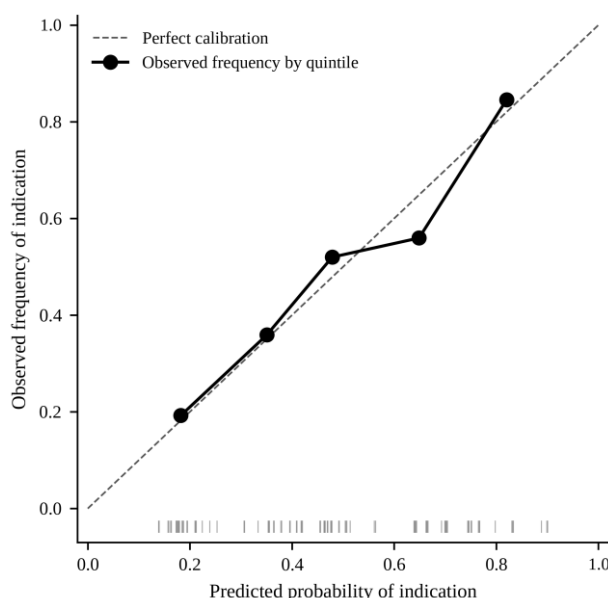


Figure 5. Calibration of the model: observed frequency of indication and predicted probability, by quintiles (Hosmer-Lemeshow $p = 0.55$; Brier score 0.199). The ticks at the bottom show the distribution of the predicted probabilities.

For descriptive purposes, the indication rate rises with the number of signs present (mass effect, hydrocephalus, intraventricular haemorrhage): from 19.4% with no sign to 90.5% when all three are present (Table IV). This gradient illustrates the logic of the decision. It is not a validated score: this would require external validation (see Discussion).

TABLE III MULTIVARIABLE LOGISTIC REGRESSION — SURGICAL INDICATION

Variable	aOR	95% CI	p
Age (per 10 years)	0.93	0.71–1.22	0.588
Glasgow Coma Scale (per point)	0.91	0.79–1.05	0.195
Haematoma volume (per 10 mL)	0.88	0.68–1.14	0.324
Mass effect	3.19	1.33–7.63	0.009
Intraventricular haemorrhage	2.42	1.04–5.63	0.041
Hydrocephalus	3.70	1.31–10.49	0.014

$n = 127$ (complete cases); events = 63; apparent AUC = 0.76; bootstrap-corrected AUC = 0.72; Hosmer-Lemeshow $p = 0.55$; Brier = 0.199; all VIF < 1.4. aOR: adjusted odds ratio.

TABLE IV SURGICAL INDICATION RATE ACCORDING TO THE NUMBER OF SIGNS OF MECHANICAL IMPACT (N = 149)

Number of signs of mechanical impact*	Patients (n)	Indication made, n (%)
0	31	6 (19.4)
1	51	23 (45.1)
2	46	29 (63.0)
3	21	19 (90.5)

*Among: mass effect, hydrocephalus, intraventricular haemorrhage. Descriptive and exploratory presentation; not a validated score.

D. Sensitivity Analyses

Two of the three factors withstand the sensitivity analyses; intraventricular haemorrhage does not. After multiple imputation of the Glasgow score (20 imputations, $n = 149$), mass effect (aOR 3.06; 95% CI 1.34–6.99; $p = 0.008$) and hydrocephalus (aOR 5.02; 95% CI 1.87–13.50; $p = 0.001$) remain independently associated with the indication. Intraventricular haemorrhage goes in the same direction, without reaching significance (aOR 1.96; 95% CI 0.90–4.28; $p = 0.091$). Age, GCS and volume remain without independent association.

In the whole stroke cohort with a known Glasgow score ($n = 219$ of 250; 91 indications), the three signs come out alone among the variables entered (age, continuous GCS, volume): mass effect (aOR 2.45; 95% CI 1.29–4.66; $p = 0.006$), intraventricular haemorrhage (aOR 2.28; 95% CI 1.15–4.51; $p = 0.018$) and hydrocephalus (aOR 4.10; 95% CI 1.91–8.82; $p < 0.001$). Discrimination is comparable (AUC 0.75) (Table V).

The article of the series devoted to the 250 patients [14], by contrast, retains disturbance of consciousness, coded yes or no (aOR 2.23; 95% CI 1.25–3.96). Here, the Glasgow score is treated as continuous and contributes no independent information: these are

What Leads to Operating on a Spontaneous Intracerebral Haemorrhage: Secondary Analysis of a Prospective Cohort of 149 Patients at Bouaké University Hospital (Côte d'Ivoire)

two ways of coding altered consciousness, not a contradiction. Moreover, in the non-haemorrhagic patients of this analysis, haematoma volume is coded as zero for lack of a measurable lesion. The analysis therefore partly separates haemorrhage and non-haemorrhage: it serves as a robustness check, not as the reference analysis.

TABLE V ROBUSTNESS OF THE THREE INDEPENDENT DETERMINANTS ACCORDING TO THE ANALYTICAL APPROACH

Analysis	Mass effect, aOR (95% CI)	Intraventricular haemorrhage, aOR (95% CI)	Hydrocephalus, aOR (95% CI)
Main — ICH, complete cases (n = 127)	3.19 (1.33–7.63)	2.42 (1.04–5.63)	3.70 (1.31–10.49)
Multiple imputation — ICH (n = 149)	3.06 (1.34–6.99)	1.96 (0.90–4.28)	5.02 (1.87–13.50)
Whole cohort with known GCS — all strokes (n = 219)	2.45 (1.29–4.66)	2.28 (1.15–4.51)	4.10 (1.91–8.82)

aOR: adjusted odds ratio. Multiple imputation: estimates pooled from the 20 imputations (Rubin's rules); intraventricular haemorrhage is no longer significant there ($p = 0.091$). In all three analyses, age, GCS and haematoma volume are not independently associated with the surgical indication.

IV. DISCUSSION

A. Main Findings

This study addresses what leads to a surgical indication in spontaneous ICH, within a West African neurosurgical cohort. Three findings stand out. An indication was made in more than one patient in two (51.7%), but nearly half of these indications (37/77) were not followed by a procedure. Three signs of mechanical impact — mass effect, hydrocephalus, intraventricular haemorrhage — are independently associated with the decision, intraventricular haemorrhage being the least robust. In our centre, neither haematoma volume, nor GCS, nor age is.

B. Interpretation: A Decision Guided by Impact, Not by Volume

This profile makes sense pathophysiologically. Mass effect, intraventricular haemorrhage and hydrocephalus are direct consequences of the haemorrhage on the brain: displacement of midline structures, blockage of cerebrospinal fluid circulation, rise in intracranial pressure [7] [17]. Hydrocephalus is moreover a recognised factor of poor prognosis in supratentorial ICH [18]. These are the mechanisms that surgery seeks to correct, whether by evacuating the haematoma, diverting the fluid or decompressing. The decision therefore rests on an immediate and reversible mechanical threat rather than on numerical thresholds. The three signs express on CT the same phenomenon: the impact of the haemorrhage on the brain, which a procedure can correct. This single logic, more than each isolated sign, seems to structure the decision.

That volume has no effect of its own may be surprising, since it weighs in the classic prognostic scores [6]. Mediation is the most likely explanation: volume acts on the decision through its consequences (mass effect, intraventricular haemorrhage, hydrocephalus), which capture most of the information once they enter the model. The odds ratio of volume changes direction, from 1.11 per 10 mL crude to 0.88 after adjustment (confidence interval including 1): this points the same way. Two haematomas of the same volume may also have very different effects depending on their location. The Glasgow score follows the same logic: its weight fades after adjustment. The neurosurgeon probably reads consciousness in the light of the scan rather than as an autonomous criterion. Imaging wins over the isolated figure.

The haemorrhage can therefore be read at two levels (Figure 6). The first, clinical and radiological severity, groups age, GCS and volume. It describes the severity of the ICH without dictating the decision on its own. The second, mechanical impact, groups mass effect, hydrocephalus and intraventricular haemorrhage. It indicates whether a procedure can change the course, and it is what guides the indication in our practice. Neurosurgeons do not operate on the size of the haematoma: they operate on its mechanical consequences, immediate and potentially reversible.

What Leads to Operating on a Spontaneous Intracerebral Haemorrhage: Secondary Analysis of a Prospective Cohort of 149 Patients at Bouaké University Hospital (Côte d'Ivoire)

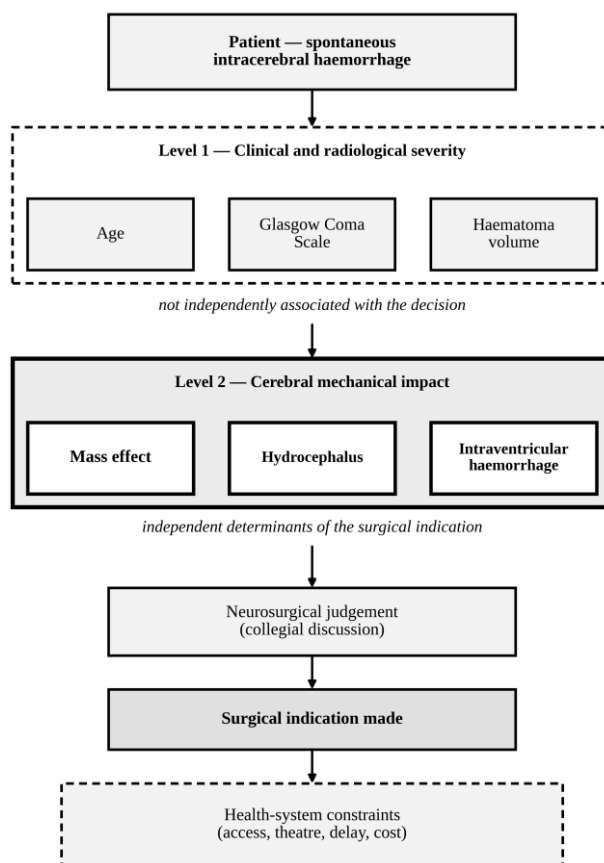


Figure 6. Conceptual framework of the decision in spontaneous ICH. Level 1 (clinical and radiological severity) describes severity without being independently associated with the decision. Level 2 (mechanical impact) groups the independent factors of the indication. Once the indication is made, health-system constraints explain the gap between indication and procedure.

C. Comparison with the Surgical Literature

These practices fall within a context of uncertainty. The trials of evacuation by open craniotomy (STICH, STICH II) showed no overall functional benefit, which tempered the idea of operating systematically on volume alone [8] [9]. Minimally invasive approaches have revived the question. MISTIE III suggested a benefit if evacuation is of good quality [10], and ENRICH showed a functional advantage of early parafascicular evacuation, especially for lobar haematomas [11]. SWITCH finally provided weak but real arguments in favour of decompressive craniectomy in severe deep haematomas, defined in particular by a volume of 30 to 100 mL and frequent intraventricular haemorrhage [12]. These works agree with our observation: it is not an isolated parameter that orients the indication, but the configuration of the lesion — location, mass effect, ventricular impact.

Our question nevertheless differs from that of these trials. They measure the effectiveness of surgery; we describe the reasoning that leads to proposing it. The factors that determine prognosis are not necessarily those that motivate a procedure. Prognosis says what is expected; the decision seeks the patients in whom a procedure can change that course. This explains why volume and GCS, well-established prognostic markers, do not remain associated with the indication after adjustment: a prognostic value is not a decisional value.

Our results thus join, with fewer resources, the logic of better-equipped teams. Hydrocephalus and intraventricular haemorrhage, associated elsewhere with mortality in this same cohort, hold a central place in surgical reasoning and justify considering external ventricular drainage early [7] [19]. Other series, in Kinshasa (volume and coma) [20] and in a large single-centre cohort (GCS, volume and intraventricular haemorrhage) [21], find these markers as predictors of mortality. A prognostic marker therefore does not mechanically become a decision criterion. Table VI places the present study among these works and reference documents.

What Leads to Operating on a Spontaneous Intracerebral Haemorrhage: Secondary Analysis of a Prospective Cohort of 149 Patients at Bouaké University Hospital (Côte d'Ivoire)

TABLE VI POSITIONING OF THE STUDY AMONG THE MAIN WORKS AND REFERENCE DOCUMENTS ON SURGERY FOR SPONTANEOUS INTRACEREBRAL HAEMORRHAGE

Study / reference document	Sample size	Subject	Main result or decision criterion
	1,033		
STICH (2005) [8]		Early surgery vs medical treatment	No overall benefit; need for selection
	601		
STICH II (2013) [9]		Superficial lobar haematomas	Possible benefit in selected patients
	506		
MISTIE III (2019) [10]		Minimally invasive evacuation + thrombolysis	Benefit conditional on the quality of evacuation
ENRICH (2024) [11]	300	Early parafascicular evacuation	Functional benefit, especially lobar haematomas
SWITCH (2024) [12]	201	Decompressive craniectomy, severe deep ICH	Weak benefit; population with marked mass effect and IVH
AHA/ASA 2022; ESO-EANS 2025 [7] [13]	Guidelines	Management of ICH	Individualised selection (consciousness, volume, topography, impact)
Komolafe / SIREN (2024) [22]	Multicentre	Prognostic factors (30-day mortality)	Intraventricular haemorrhage: marker of severity
Limann, Ghana (2024) [23]	168	In-hospital mortality	Hydrocephalus and low GCS associated with death
Present study (Bouaké, 2022–2023)	149	Determinants of the surgical decision	Mass effect, hydrocephalus, intraventricular haemorrhage

Indicative comparison; the series differ in their objective (effectiveness, prognosis, decision) and in their context. IVH: intraventricular haemorrhage.

D. From Indication to Procedure: A Revealing Gap

Here is the most striking lesson: deciding to operate does not mean operating. An indication was made in 77 patients and only 40 were operated on. Nearly one indication in two (37/77) was therefore not followed by a procedure. We recorded the reasons chart by chart for these 37 patients: financial obstacle (8), operating theatre unavailable (8), clinical deterioration (4), death before surgery (3), family refusal (4) and undocumented reason (10). Material obstacles, money and theatre in equal parts, explain 16 cases out of 37 (43%). Deterioration and preoperative death (7 patients) reflect an unfavourable course before the procedure rather than an access obstacle: for them, the indication became obsolete. Ten reasons (27%) remain unknown. This gap, rarely quantified in the international literature, illustrates a major obstacle of neurosurgery in sub-Saharan Africa. It deserves a separate study on barriers to access.

E. Implications for Practice and Public Health

Making a centre's criteria explicit serves two causes. In training, a reasoning that has remained implicit is more easily transmitted, and differences between practitioners are reduced. For the organisation of care, the gap between indication and procedure argues for strengthening neurosurgical pathways and emergency operating capacity, and for taking non-medical obstacles into account in health policy. These are central issues of global neurosurgery, which aims at equitable access to safe and affordable neurosurgical care in low- and middle-income countries [4].

F. Clinical Implications

CT reports should systematically mention mass effect, hydrocephalus and intraventricular haemorrhage.

A single one of these signs should trigger a rapid neurosurgical opinion.

These signs are visible on a standard CT scan, without volumetry or advanced imaging, and are simple to spot. Using them could harmonise indications between resource-limited centres.

The number of signs present (0 to 3) follows a clear gradient in the use of surgery (from 19% to 91%). It is a simple bedside marker, to be confirmed by external validation before any formal use.

Reducing the gap between indication and procedure also requires acting on non-medical obstacles: cost, referral delays, theatre availability.

What Leads to Operating on a Spontaneous Intracerebral Haemorrhage: Secondary Analysis of a Prospective Cohort of 149 Patients at Bouaké University Hospital (Côte d'Ivoire)

G. Strengths and Limitations

This study has in its favour its prospective character, factors chosen in advance for their clinical relevance, a check of collinearity, discrimination and calibration, and consistent results across the sensitivity analyses. Intraventricular haemorrhage, however, does not withstand imputation.

Several limitations should be kept in mind. The study is observational and single-centre: the practices described do not necessarily generalise. Haematoma location, yet decisive in the choice of procedure (lobar, deep, cerebellar), was recorded in only one chart. Its systematic re-reading on the images should be a priority. We describe the indication, not its appropriateness: we do not judge its relevance against patient outcome, which exposes the study to the indication bias inherent in observational studies. Decisions rested on the team's expertise and were not protocolised. This is faithful to real practice, but the inter-observer reproducibility of the radiological signs, in particular mass effect and hydrocephalus, was not assessed. The reasons for non-performance, reconstructed after the fact, remain unknown for 10 of the 37 patients.

The main analysis relied on complete cases ($n = 127$), the missing data concerning mainly the GCS. Multiple imputation confirmed mass effect and hydrocephalus; intraventricular haemorrhage, whose confidence interval includes 1 after imputation, remains a more fragile association. The number of events required a parsimonious model, and the estimates, notably the wide interval of hydrocephalus, remain exploratory. The moderate sample size limits precision. The analysis on the whole cohort ($n = 219$) codes volume as zero in non-haemorrhagic patients: it is valid only as a robustness check. Finally, the model was not validated on another sample. The bootstrap-corrected AUC (0.72) attenuates this gap without closing it, and this validation remains necessary before any transposition.

H. Perspectives

This study comes from a single resource-limited centre, but it rests on universal pathophysiological mechanisms. These determinants could therefore hold elsewhere, subject to multicentre validation. The natural next steps are to reconstruct haematoma location from the images, to analyse together the indication and its performance, and to link the decision criteria to functional outcome (modified Rankin Scale, mRS). The factors identified could one day form the basis of a decision-support tool. It would then have to be developed according to the TRIPOD recommendations [24], validated internally then externally in several centres — ideally within a West African registry [25] — and its clinical impact measured before any routine use, to avoid overfitting. We have therefore not sought to propose a score here.

V. CONCLUSION

In this Ivorian cohort of spontaneous intracerebral haemorrhages, the surgical indication follows the signs of mechanical impact — mass effect, hydrocephalus, intraventricular haemorrhage, the latter being the most fragile association — rather than haematoma volume, GCS or age. This profile is consistent with a decompression logic and joins the recent data on ICH surgery. The gap between indications made and procedures performed reveals unmet neurosurgical needs and the urgency of strengthening operative capacity. A multicentre validation in sub-Saharan Africa will tell whether this framework generalises and whether it can become a decision-support tool.

VI. DECLARATIONS

- 1) **Ethical Approval:** See the Ethical Considerations section: authorisation of the head of department and of the hospital management during the study, then approval of the Institutional Ethics Committee of Bouaké University Hospital (No. CEI/CHU-BKE/102/2026), in accordance with the Declaration of Helsinki.
- 2) **Consent:** Individual consent was waived, covered by the ethical approval (data collected as part of routine care and analysed in anonymised form). The manuscript contains no data allowing a patient to be identified.
- 3) **Data Availability:** The data are available from the corresponding author on reasonable request.
- 4) **Funding:** No specific funding.
- 5) **Conflicts of Interest:** The authors declare no conflicts of interest.
- 6) **Author Contributions (CRediT):** Serge Konan Yao: conceptualisation, methodology, writing. Landry Stéphane Faozo Teti: conceptualisation, analysis, writing and review. Djoko Traoré: data collection and validation. Adama Kouadio: data collection and resources. Koffi Jean-Jacques Kouassi: methodology, validation and supervision. Aderehime Haidara: supervision, validation and review. All authors approved the final version.

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What Leads to Operating on a Spontaneous Intracerebral Haemorrhage: Secondary Analysis of a Prospective Cohort of 149 Patients at Bouaké University Hospital (Côte d'Ivoire)

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What Leads to Operating on a Spontaneous Intracerebral Haemorrhage: Secondary Analysis of a Prospective Cohort of 149 Patients at Bouaké University Hospital (Côte d'Ivoire)

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