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Anterior Cranial Fossa Fractures: CSF Leak, Meningitis and Management in 114 Patients at Bouaké University Hospital

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Abstract

Background. Anterior cranial fossa fractures (ACFF) open a direct route between the paranasal sinuses and the subarachnoid space, exposing patients to cerebrospinal fluid (CSF) leak and meningitis. Data from sub-Saharan Africa, where motorcycle crashes dominate, are scarce.

Objective. To describe ACFF and their leak-related complications (CSF fistula, meningitis) in a West African neurosurgical cohort, and to explore the lesional factors associated with them.

Methods. Single-centre observational study (STROBE) drawn from the institutional head-injury database of Bouaké University Hospital (1,366 patients). We analysed the 114 patients of the recent series (2025–2026), in whom complications were recorded in a standardised way. The primary outcome was a CSF fistula and/or meningitis. Groups were compared with Fisher's exact and Mann–Whitney tests, and crude and Firth odds ratios (OR) are reported. With 10 events, no conventional multivariable model was fitted; one two-variable Firth model is shown for illustration only. Missing values were not imputed.

Results. Patients were young men (mean age 29.7 years; 93.9% male) injured in road-traffic crashes (92.1%), mostly on motorcycles. Median Glasgow Coma Scale score was 13 (mild injury in 63.2%). The most frequent associated lesions were contusion (62.3%), facial fracture (43.0%) and an evident osteodural breach (28.1%). Ten patients (8.8%) had a leak-related complication: 8 CSF fistulas (7.0%) and 2 cases of meningitis (1.8%). No association was significant. Pneumocephalus (Firth OR 4.2; 95% CI 0.97–18.1; Fisher p = 0.087) and an evident osteodural breach (OR 2.8; 95% CI 0.79–10.1; p = 0.140) were more frequent in patients with a

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complication, and both meningitis cases had a depressed fracture. Skull-base repair was documented in 66.7% of patients, antibiotics were given to 88.6% and vaccination against encapsulated bacteria to 63.2%. Outcome was documented in 108 patients (94.7%); all 10 complications had a favourable outcome, and the 3 in-hospital deaths (2.6%) were not attributed to fistula or meningitis.

Conclusion. CSF fistula and meningitis were uncommon (8.8%) and had a favourable course. Management was broad and uncompared, so the effect of any of its components cannot be judged. Pneumocephalus and an evident osteodural breach remain hypotheses for larger multicentre studies.

Keywords: Anterior cranial fossa fracture; Skull base fracture; Cerebrospinal fluid leak; Meningitis; Pneumocephalus; Neurosurgery; Maxillofacial surgery; Côte d'Ivoire; Sub-Saharan Africa.

1. Introduction

The floor of the anterior cranial fossa separates the brain from the nasal cavities and paranasal sinuses by thin bony laminae: the cribriform plate, the ethmoid roof, the posterior wall of the frontal sinus and the orbital roof (Figure 1). Its fractures (anterior cranial fossa fractures, ACFF) are thought to account for about 4% of head injuries and up to one fifth of skull fractures; the anterior fossa is the most frequent site of skull-base fractures [1,2]. The dura adheres to bone there: when the fracture is displaced it is often torn, and the osteodural breach (ODB) then brings the subarachnoid space into contact with contaminated air-filled cavities [2,3]. Several clinical and radiological classifications of frontobasal trauma have been proposed [4].

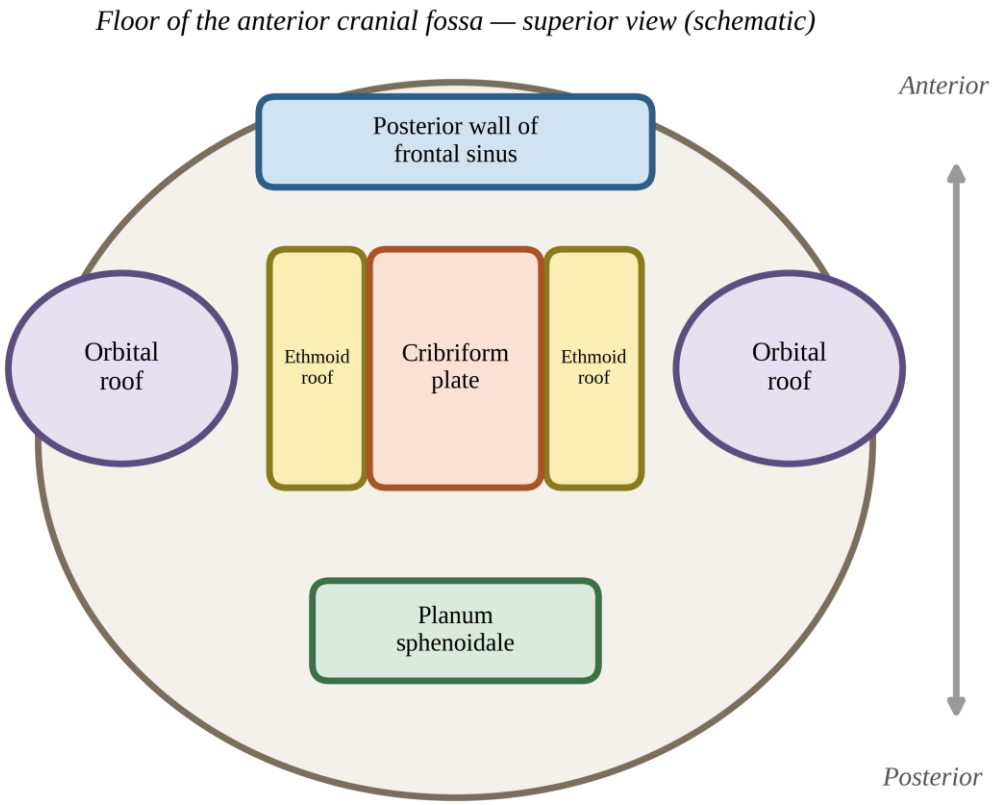


Figure 1. Schematic representation of the floor of the anterior fossa (superior view) and the main sites of fracture and osteodural breach: posterior wall of the frontal sinus, ethmoid roof, cribriform plate, orbital roof and planum sphenoidale.
Note. Illustrative diagram, not to scale.

Two complications follow: cerebrospinal fluid (CSF) fistula, which presents as rhinorrhoea, and post-traumatic meningitis, the risk of which persists as long as the breach remains open [3,5,6]. These fractures fall under neurosurgery, maxillofacial surgery and otorhinolaryngology (ENT) alike, which partly explains why they are seldom reported. Published series are mostly single-centre and retrospective [7,8], and the literature from sub-Saharan Africa remains fragmentary [9–11].

Head injuries weigh heavily on sub-Saharan Africa [12,13], where two-wheeler crashes predominate [11,14,15]. Admission delays there are long and access to fine imaging and skull-base surgery is uneven, which may change the presentation and prognosis of these lesions [9,10]. Bouaké University Hospital, the main neurosurgical referral centre for central Côte d'Ivoire, maintains a head-injury database from which we identified a series of ACFF that is large for the

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region. We aimed to (i) describe the epidemiological, clinical and lesional profile of these fractures, (ii) describe their breach-related complications and management, (iii) explore the lesional factors associated with a CSF fistula or meningitis, and (iv) test, on an exploratory basis, the robustness of these associations using methods suited to rare events.

2. Patients and Methods

2.1 Study design and population

This single-centre observational study was conducted in the Department of Neurosurgery of Bouaké University Hospital and is reported according to the STROBE guidelines [16]. It is based on a retrospective analysis of the institutional head-injury database, fed by the register of consecutive admissions and the operative register. The database comprises 1,366 patients: a retrospective historical phase and a recent phase (2025–2026; 772 patients), for which pathway variables and complications were collected in a standardised way.

We included patients with ACFF confirmed on computed tomography (CT), regardless of age. ACFF was defined as a fracture of the floor of the anterior fossa (cribriform plate, ethmoid roof, orbital roof, planum sphenoidale or posterior wall of the frontal sinus) visible on bone windows, with multiplanar reconstructions when available. ODB was recorded when a bony discontinuity was associated with evidence of dural rupture: pneumocephalus, CSF leak, dural exposure or operative finding. This definition partly overlaps with pneumocephalus and CSF leak, which limits the independence of these variables (see Strengths and limitations). Meningitis was diagnosed on combined clinical, laboratory and, when available, microbiological evidence.

One hundred and eighteen patients had an ACFF. The 4 patients from the historical phase, none of whom had a documented complication, were excluded; the analysis therefore covers the 114 patients from the recent phase (Figure 2), i.e. 14.8% of the 772 patients in this phase.

2.2 Overlap with other work drawn from the cohort

These patients come from the institutional database of Bouaké University Hospital, which feeds other manuscripts in preparation (epidemiology and mortality of the cohort, prehospital pathway, paediatric subgroup, infectious complications of depressed fractures and craniocerebral wounds; unpublished). The present work asks its own question and uses its own outcome; it shares with them only the general characteristics of the cohort. Patients with a depressed fracture or a craniocerebral wound may appear in several of these works. This overlap is disclosed here and in the cover letter, in accordance with the recommendations of the International Committee of Medical Journal Editors.

2.3 Institutional care setting

Patients were managed in a single department by the same neurosurgical team. The strategy formalised by the department was as follows: confirm the ACFF on CT, look for rhinorrhoea and

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an ODB, repair the skull base in case of a patent breach, an open depressed fracture or a craniocerebral wound (CCW), and monitor in other cases. Conservative treatment combined bed rest, head elevated to 30°, avoidance of Valsalva manoeuvres, symptomatic treatment and daily monitoring of rhinorrhoea. Decisions were collegial, involving stomatology, maxillofacial surgery, ENT and ophthalmology as needed.

Antibiotic therapy and vaccination against encapsulated bacteria were prescribed on clinical judgement, in the presence of a breach or sinus violation; prophylactic and curative antibiotic therapy were not distinguished. As the results show, practice was broader than this strategy, and the reasons for individual decisions were not recorded. Complications were looked for during hospitalisation and at each follow-up visit, until the last documented visit.

2.4 Variables, definitions and outcome

We collected sociodemographic data, mechanism, admission delay, Glasgow Coma Scale (GCS) score and severity (mild 13–15, moderate 9–12, severe ≤ 8), the CT lesion profile (contusion, depressed fracture, CCW, haematomas, subarachnoid haemorrhage, pneumocephalus, facial fracture, mass effect), evident ODB, management (anterior skull-base repair, elevation of depressed fracture, debridement, antibiotic therapy, vaccination, specialist opinions) and outcome (in-hospital mortality, Glasgow Outcome Scale [GOS], follow-up). A senior neurosurgeon interpreted the CT, with collegial review by a radiologist in case of doubt. ODB and pneumocephalus were recorded from this interpretation, the radiology report and the clinical or operative record, without standardised independent radiological review. A procedure was considered documented when it appeared in the operative register, whose completeness could not be verified against source records.

The primary outcome was the breach-related complication: CSF fistula (clinical rhinorrhoea, without β2-transferrin assay) and/or post-traumatic meningitis, observed during hospitalisation or follow-up. It distinguishes neither leaks present at admission from those appearing later, nor their timing in relation to repair.

2.5 Statistical analysis

Categorical variables are described as counts and percentages, quantitative variables as mean ± standard deviation or median [interquartile range, IQR]. We compared patients with and without a complication using Fisher's exact test (categorical variables) and the Mann–Whitney test (quantitative variables). Crude odds ratios (OR) are the reference estimates; they cannot be calculated when a cell is zero.

With only 10 events, we also estimated ORs by Firth penalised logistic regression [17], with profile-likelihood confidence intervals and a penalised likelihood-ratio test. For a single binary predictor, the Firth OR is identical to the Haldane–Anscombe corrected OR (0.5 added to each cell): it corrects estimation bias but does not independently confirm the univariable analysis. We

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fitted no conventional logistic regression for this outcome; a two-variable Firth model (pneumocephalus and ODB) is shown for illustration only. A sensitivity analysis excluded CCWs and then depressed fractures in succession. An exploratory anatomical score (sum of five lesions selected a priori: pneumocephalus, ODB, depressed fracture, CCW, facial fracture) was evaluated by the area under the ROC curve (AUC; 95% CI by bootstrap). The determinants of skull-base repair (76 repairs) were studied by univariable analysis and then multivariable logistic regression. These complementary analyses were planned as exploratory: they generate hypotheses and establish no causality.

The significance threshold was $p < 0.05$, without correction for multiple comparisons. Analyses were performed in Python 3.12 (pandas, SciPy, statsmodels); Firth regression follows the method of Heinze and Schemper [17]. No sample size calculation was made: all eligible patients were included. The main admission variables and the lesion profile were complete; GOS was missing in 6 patients (5.3%), lost to follow-up. No data were imputed. Anonymised data and analysis code are available on reasonable request.

3. Results

3.1 Sociodemographic profile, circumstances and clinical presentation

Of the 118 ACFF identified, 114 were analysed (Figure 2). Patients were young men (mean age 29.7 years; 93.9% male; Table 1). Road-traffic crashes predominated (92.1%), especially among motorcyclists (82.5%). Nearly two thirds of patients (63.2%) had been referred from another facility, with a median admission delay of 2 days [IQR 1–3]. On admission, median GCS was 13 [IQR 12–15]: injury was mild in 63.2% of patients, moderate in 29.8% and severe in 7.0%. Initial loss of consciousness was reported in 57.0% of them. Other presenting signs were repeated vomiting (25.4%), focal neurological deficit (10.5%), seizure (8.8%) and anisocoria (6.1%).

Table 1. Sociodemographic characteristics and circumstances of injury (N = 114).

Variable	n	%
Age, mean ± SD (median [IQR]; range: 28 [20–37]; 5–59)	29.7 ± 11.7	—
Male sex	107	93.9
Female sex	7	6.1
Age < 16 years	11	9.6
Road-traffic crash	105	92.1
Two-wheeler user (motorcyclist)	94	82.5
Fall	4	3.5
Work-related accident	3	2.6
Assault	2	1.8
Referred patient	72	63.2

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Variable	n	%
Admission delay, median [IQR], days	2 [1–3]	—
GCS on admission, median [IQR]	13 [12–15]	—
Mild injury (GCS 13–15)	72	63.2
Moderate injury (GCS 9–12)	34	29.8
Severe injury (GCS ≤ 8)	8	7.0
Initial loss of consciousness	65	57.0
Repeated vomiting	29	25.4
Focal neurological deficit	12	10.5
Seizure	10	8.8
Anisocoria	7	6.1

Compared with the 772 head-injured patients of the recent phase, patients with ACFF were more often men (93.9% vs 83.8%), more often referred (63.2% vs 50.4%) and slightly more often victims of a road-traffic crash (92.1% vs 89.4%). Median GCS was identical (13) and the severity distribution similar (mild: 63.2% vs 56.2%; moderate: 29.8% vs 35.9%; severe: 7.0% vs 7.9%). These differences were not tested.

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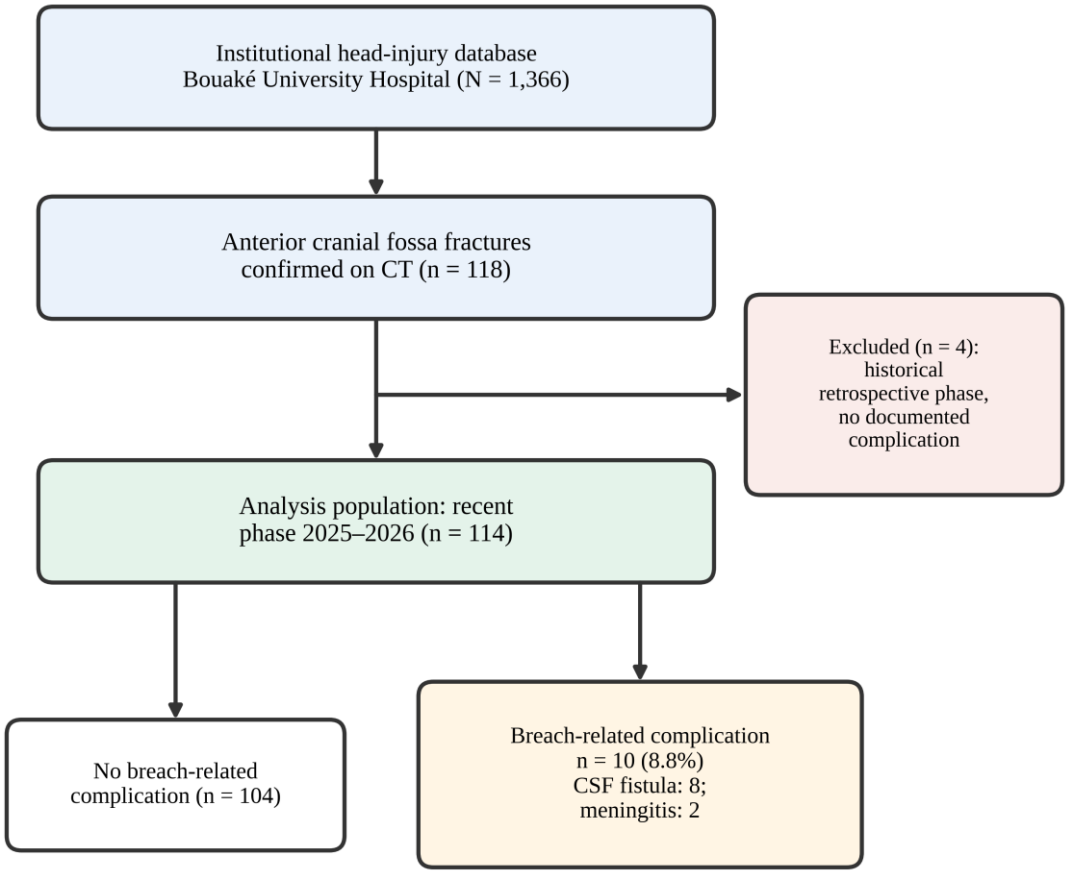


Figure 2. Flow diagram (STROBE): selection of the population and distribution according to the breach-related complication.

Note. Four patients of the historical phase, with no documented complication, were excluded, leaving 114 analysable patients.

3.2 Lesion profile and osteodural breach

Most patients had associated lesions (Figure 3, Table 2). Contusion or intraparenchymal haematoma predominated (62.3%), and 43.0% of patients had a facial fracture, a sign of craniofacial trauma. An evident ODB was documented in 28.1% of patients and pneumocephalus in 11.4%. Depressed fracture (16.7%) and CCW (12.3%) were less frequent.

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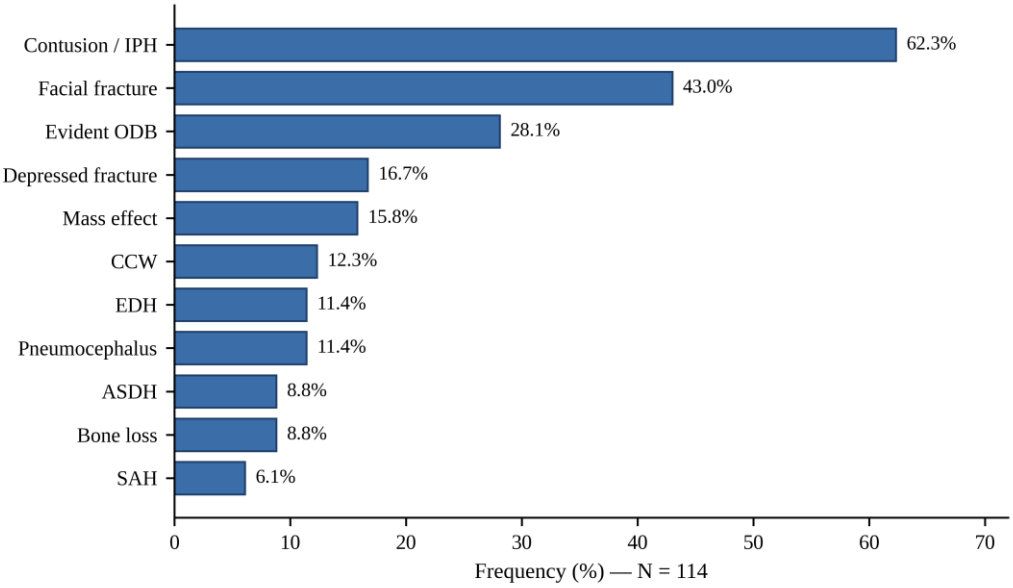


Figure 3. Descriptive frequencies (%) of the main lesions associated with ACFF (N = 114).
Note. Descriptive histogram, without error bars. IPH: intraparenchymal haematoma.

Table 2. CT lesion profile and associated lesions (N = 114).

Associated lesion	**n**	**%**
Contusion / intraparenchymal haematoma	71	62.3
Facial fracture	49	43.0
Evident osteodural breach	32	28.1
Depressed skull fracture	19	16.7
Intracranial mass effect	18	15.8
Craniocerebral wound (CCW)	14	12.3
Extradural haematoma (EDH)	13	11.4
Pneumocephalus	13	11.4
Acute subdural haematoma (ASDH)	10	8.8
Loss of bone substance	10	8.8
Subarachnoid haemorrhage (SAH)	7	6.1

Note. Several lesions could coexist in the same patient; percentages therefore do not total 100%.

3.3 Management

A surgical indication had been recorded in 97 patients (85.1%); 84 (73.7%) had at least one neurosurgical procedure documented in the operative register, i.e. 86.6% of indications (Table 3). For the remaining 13 patients, the reason for no procedure (death before surgery, refusal, discharge, recording failure) is not known.

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The anterior skull base was repaired (revision ± duroplasty) in 76 patients (66.7%), 8 of them as delayed "cold" repairs. This exceeds the number of patients meeting any of the department's three indication criteria (evident ODB, depressed fracture, CCW: 65 at most, overlaps not deducted): at least 11 repairs therefore fell outside these criteria. A depressed fracture was elevated in 12 patients and a CCW debrided in 13. Antibiotics were prescribed to 101 patients (88.6%) and vaccination against encapsulated bacteria (pneumococcus, meningococcus, Haemophilus) to 72 (63.2%); antibiotics were thus prescribed almost systematically, well beyond the 32 patients with an evident ODB. A stomatology or maxillofacial opinion was requested for 71.9% of patients, an ophthalmology opinion for 27.2% and an ENT opinion for only 5.3%.

Table 3. Therapeutic management (N = 114).

Therapeutic modality	**n**	**%**
Surgical indication	97	85.1
At least one documented neurosurgical procedure	84	73.7
Anterior skull-base repair (± duroplasty)	76	66.7
of which delayed "cold" repair	8	7.0
Debridement of craniocerebral wound	13	11.4
Elevation of depressed fracture	12	10.5
Craniectomy	10	8.8
Antibiotic therapy	101	88.6
Vaccination against encapsulated bacteria	72	63.2
Stomatology / maxillofacial opinion	82	71.9
Ophthalmology opinion	31	27.2
ENT opinion	6	5.3

Note. Categories are not mutually exclusive.

3.4 Breach-related complications: CSF fistula and meningitis

Ten patients (8.8%) had a breach-related complication: 8 CSF fistulas (7.0%) and 2 post-traumatic meningitis (1.8%), with no overlap. Including the other infectious complications recorded (sepsis, suppuration), 14 patients (12.3%) had an infectious complication. Both meningitis cases occurred in patients with a depressed fracture, open in one case; none of the 8 patients with a fistula had a depressed fracture. All 10 complications had a favourable course (GOS 4–5), with no attributed death.

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3.5 Factors associated with fistula and/or meningitis

No association reached the significance threshold, which is unsurprising with 10 events and such wide intervals (Table 4). Pneumocephalus and evident ODB were more frequent in patients with a complication, though the difference cannot be distinguished from chance. Median age (33 years in patients with a complication vs 28; p = 0.309), median GCS (14 vs 13; p = 0.484) and median admission delay (2 days in both groups; p = 0.927) did not differ.

Table 4. Lesional factors associated with the occurrence of a CSF fistula and/or meningitis (10 events): exploratory univariable analysis.

Factor	**With the factor: complication/total (%)**	**Without the factor: complication/total (%)**	**Crude OR**	**Firth OR [95% CI]**	**p (Fisher)**
Pneumocephalus	3/13 (23.1%)	7/101 (6.9%)	4.0	4.2 [0.97–0.087 18.1]	
Evident ODB	5/32 (15.6%)	5/82 (6.1%)	2.9	2.8 [0.79–0.140 10.1]	
Depressed fracture	2/19 (10.5%)	8/95 (8.4%)	1.3	1.5 [0.32–0.672 6.8]	
Facial fracture	3/49 (6.1%)	7/65 (10.8%)	0.5	0.6 [0.15–0.511 2.2]	
CCW	0/14 (0%)	10/100 (10.0%)	not calculable	0.3 [0.01–0.609 5.9]	

Note. Fisher's exact test; crude OR (not calculable when a cell is zero); Firth OR, with 95% CI by profile likelihood. No conventional multivariable modelling was performed.

3.6 Complementary analyses

The Firth ORs (Table 4, Figure 4) are identical, factor by factor, to the Haldane–Anscombe corrected ORs: they therefore do not independently confirm the univariable analysis. The penalised test gave p = 0.066 for pneumocephalus and p = 0.074 for evident ODB, without changing the reading. In a two-variable Firth model, purely illustrative, each association weakened in the presence of the other (pneumocephalus: adjusted OR 3.3; ODB: 2.3), as expected since the definition of ODB partly includes pneumocephalus.

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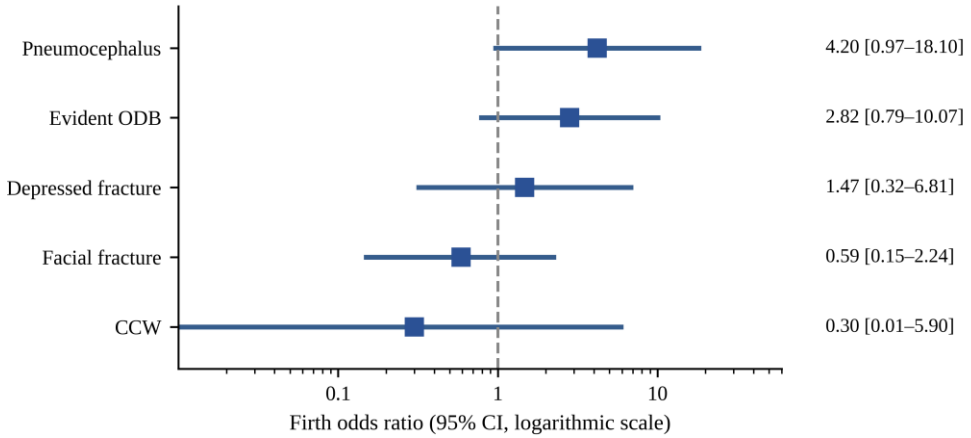


Figure 4. Firth odds ratios (95% CI, logarithmic scale) of the factors studied for the occurrence of a CSF fistula and/or meningitis.
Note. The vertical line indicates no association (OR = 1). Exploratory analysis (10 events).

The sensitivity analyses did not change the direction of the associations. Excluding CCWs (14 patients, no events) left the estimates practically unchanged (pneumocephalus OR 3.4; ODB 2.9), which is uninformative, since no event was removed. Excluding depressed fractures (19 patients, including both meningitis cases: the outcome was then reduced to the 8 fistulas) slightly strengthened the estimates (pneumocephalus OR 5.2, p = 0.061; ODB 4.4, p = 0.054). The exploratory anatomical score did not discriminate patients with a complication (AUC 0.56; 95% CI 0.40–0.72): the complication rate did not rise steadily with the score, and no useful threshold emerged.

The anterior skull base was repaired in 76 patients (66.7%). No lesional or clinical characteristic was significantly associated with repair, either in univariable analysis or in multivariable regression (Table 5). The clearest, non-significant, associations concerned depressed fracture (adjusted OR 2.3; 95% CI 0.7–7.5) and CCW (2.1; 0.5–8.4). The absence of any determinant despite 76 events suggests a broad repair policy rather than selection guided by a radiological criterion, as the at least 11 repairs outside the criteria confirm.

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Table 5. Determinants of anterior skull-base repair (76 repairs out of 114), multivariable logistic regression adjusted simultaneously for depressed fracture, CCW, evident ODB, pneumocephalus, facial fracture and extradural haematoma.

Factor	Repair	Not repaired	Adjusted OR [95% CI]	p
Depressed fracture	15/19 (79%)	4/19 (21%)	2.3 [0.7–7.5]	0.178
CCW	11/14 (79%)	3/14 (21%)	2.1 [0.5–8.4]	0.285
Evident ODB	23/32 (72%)	9/32 (28%)	1.4 [0.6–3.7]	0.468
Pneumocephalus	9/13 (69%)	4/13 (31%)	1.2 [0.3–4.4]	0.782
Facial fracture	33/49 (67%)	16/49 (33%)	1.1 [0.5–2.4]	0.877
Extradural haematoma	8/13 (62%)	5/13 (38%)	0.8 [0.2–2.9]	0.782

Note. No association reached significance; McFadden pseudo-R^2 = 0.03. “Not repaired” denotes patients with no documented repair, whether or not operated on otherwise.

With 7 patients with an unfavourable outcome (GOS 1–3) among the 108 evaluable, no modelling of functional outcome was possible; we describe it only.

3.7 Outcome

In-hospital mortality was 2.6% (3/114). The three deaths were attributed to sepsis, brain herniation and status epilepticus. The source of the sepsis is not specified in the database: this death was not attributed to a fistula or meningitis, but a link with the breach cannot be excluded with certainty. GOS was documented in 108 patients (94.7%); 6 (5.3%) were lost to follow-up. Among the 108 evaluable patients, 101 (93.5%) had a favourable outcome (GOS 4–5), 4 remained severely disabled or in a vegetative state (GOS 2–3) and 3 had died (GOS 1), with a median follow-up of 14 months [IQR 9–19]. No late reoperation was recorded.

4. Discussion

4.1 Main result

CSF fistula (7.0%) and meningitis (1.8%) were rare in this series of 114 ACFF, and all had a good course, with no attributed death. These are direct observations, as is the presence of a depressed fracture in both patients with meningitis. The role of pneumocephalus and ODB as risk factors remains a hypothesis: more frequent in patients with a complication, these two variables do not reach significance and their intervals are wide. Depressed fracture illustrates the fragility of this kind of observation: present in both meningitis cases, it is nevertheless not associated with the composite outcome (Firth OR 1.5). Two cases cannot support a conclusion.

4.2 Anatomical and pathophysiological bases

The cribriform plate, perforated by the olfactory filaments and crossed by the ethmoidal artery, and the very thin ethmoid roof are the usual sites of breaches, because the dura is firmly adherent to the bone at these sites. A fracture with little displacement, or remote from these fragile areas,

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may remain silent. Pneumocephalus and ODB probably mark a wider osteodural communication rather than cause it, all the more so as the definition of ODB partly includes pneumocephalus and the leak itself. Post-traumatic pneumocephalus also has its own complications [18]. Since the absence of an initial leak does not exclude an ODB, delayed rhinorrhoea must be looked for during monitoring.

4.3 Operative decision and collaboration between specialties

These fractures most often occur within craniofacial trauma: nearly half of the patients had a facial fracture, and a stomatology or maxillofacial opinion was requested for 71.9% of them, against 5.3% for ENT. The collaboration documented here is thus first that of neurosurgery with maxillofacial surgery, which the literature recommends for leaks associated with craniomaxillofacial trauma [5,19]. The role of ENT surgeons, decisive for the endonasal route, has yet to be established in our centre, where no exclusive endonasal repair was possible. Pneumocephalus or an evident ODB should prompt closer monitoring of rhinorrhoea and early discussion of repair at a multidisciplinary meeting.

4.4 Repair and antibiotic therapy: the gap between practice and recommendations

The department's strategy reserved repair for patent breaches, open depressed fractures and CCWs. In practice, 76 patients (66.7%) were repaired, more than the 65 at most who met one of these criteria, and no lesional characteristic predicted repair. The policy applied was therefore broader than the stated policy, and the reasons for individual decisions were not recorded. This proportion is high in relation to the literature, where repair mainly targets patent or persistent breaches, many early fistulas drying up on their own [7,20,21].

Antibiotics, prescribed to 88.6% of patients, amount to near-systematic prophylaxis. The Cochrane meta-analysis showed no benefit of routine antibiotic prophylaxis [6], and published meta-analyses diverge [22]. The value of vaccination against encapsulated bacteria (63.2%) is likewise debated. Without a comparator, so broad a strategy precludes attributing the rarity of complications to any of its elements: it may just as well reflect overprescription, under-detection of transient fistulas, or the spontaneously favourable course of most ACFF.

4.5 Comparison with the literature

The frequency of CSF fistula after skull-base fracture varies widely across series and definitions, generally between 10 and 30% [2,3,21]. Our rate (7.0%) is below this range, with a different denominator: all ACFF here, skull-base fractures elsewhere. It may reflect under-detection of transient fistulas, in a context of long admission delays and without β2-transferrin assay, or the effect of a very broad repair policy. The risk of meningitis is classically linked to persistence of the fistula beyond 7 to 10 days [3,6]. Other work has studied the factors in the course of traumatic CSF leaks [23]; our number of events does not allow us to set our results against theirs. The available West African series are limited to patients with proven rhinorrhoea [9,10]. Based on a non-systematic literature search, our series differs in describing the full spectrum of ACFF,

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not only fistulising forms. We present separately the series not restricted to fistulas (Table 6a) and those limited to fistulas or rhinorrhoea (Table 6b), whose complication rates are not comparable. The male and motorcycle predominance and the admission delays match the regional profile of head injuries [11,13,14].

Table 6a. Series of anterior fossa trauma not restricted to fistulas.

Series (year)	Country/setting	n	Mean age	% M
Our study	Côte d'Ivoire (LR)	114	29.7	93.9
Piccirilli et al. (2012) [8]	Italy	223	NR	NR

Note. NR: not reported; LR: limited resources. The two Italian series come from the same team and may partly overlap.

Table 6b. Series restricted to CSF fistulas, post-traumatic rhinorrhoea, or fractures with pneumocephalus/fistula.

Series (year)	Country/setting	n	Population	Mean age	% M
Piccirilli et al. (2025) [21]	Italy	314	Frontobasal fractures with pneumocephalus and/or fistula	NR	NR
Bah et al. (2026) [9]	Guinea (LR)	43	ACFF with fistula	38	65
Ismail et al. (2020) [10]	Nigeria (LR)	20	Post-traumatic rhinorrhoea	30.5	100

Note. As these series include only patients who already had a fistula or a proven breach, their complication rates are not comparable with those of a consecutive series.

4.6 Anterior skull-base repair techniques

Repair aimed to close the osteodural communication and isolate the endocranium from air-filled cavities. We mainly used the high route (subfrontal, by flap or craniectomy) with duroplasty, supplemented as needed by cranialisation of the frontal sinus and repair of facial injuries. The literature describes varied techniques: autologous bone fragments [24], vascularised flaps and above all the endoscopic endonasal approach, with promising results and reduced morbidity [19,25]. The choice depends on the site of the breach, associated intracranial lesions and available resources. Recent algorithms make a fistula or pneumocephalus persisting for several days an indication for repair [7,21], which corresponds to the delayed "cold" strategy applied in 8 of our patients. No exclusive endonasal route was available in our centre during the study, and reconstruction materials depended on local stocks.

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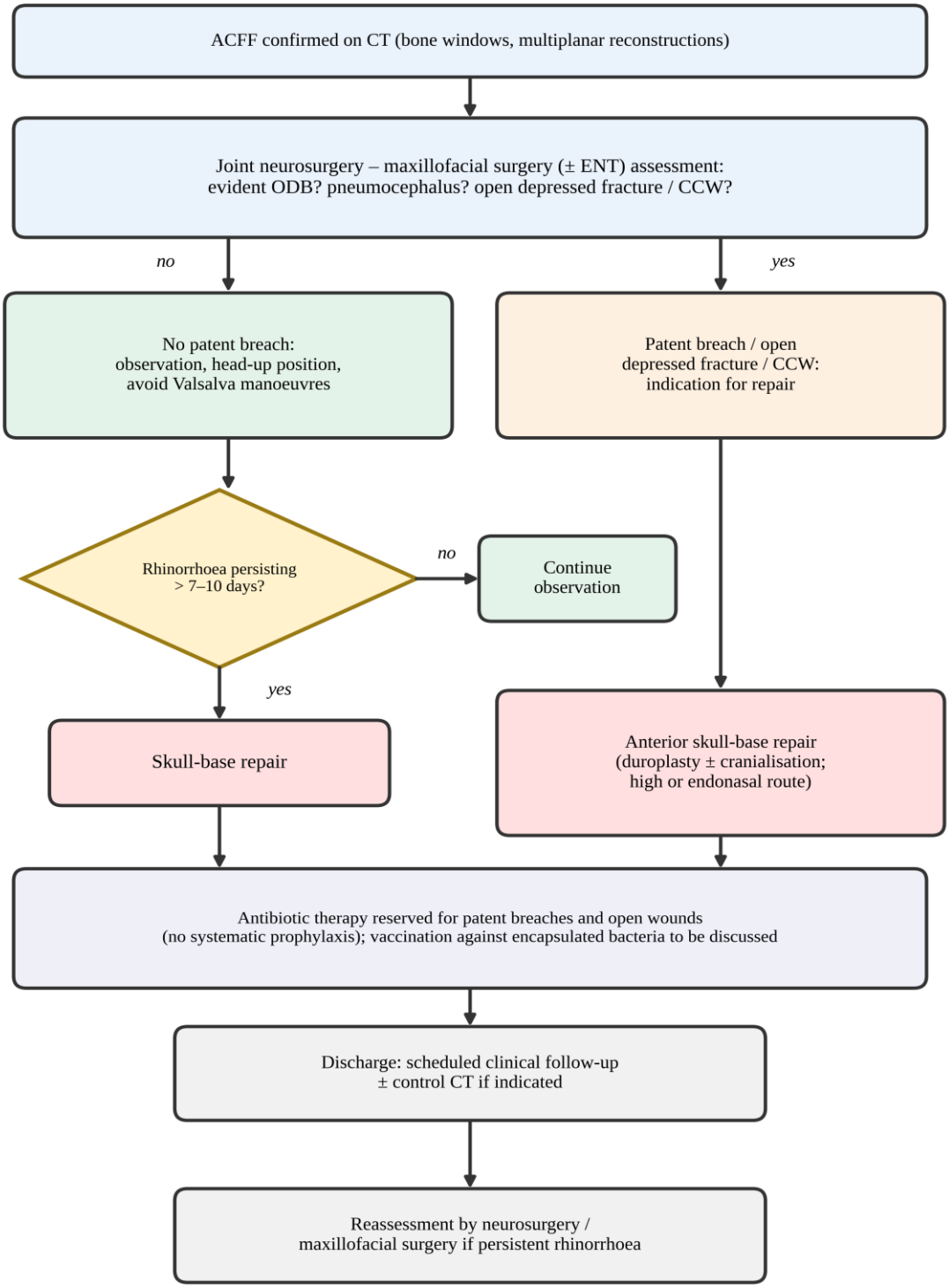
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4.7 Implications for clinical practice

These results serve to prioritise monitoring, not to set decision criteria: look for pneumocephalus and ODB on the initial CT, monitor rhinorrhoea, involve the relevant specialties early, adapt the strategy to available means (Figure 5). A depressed fracture, especially open, should raise concern for direct contamination, even though this association rests here on only two cases. The algorithm in Figure 5 draws on the literature and the department's experience; it departs from observed practice (antibiotics, extent of repair) and is not validated. Figure 6 summarises the patient pathway.

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Figure 5. Simplified management algorithm for ACFF, proposed from the literature and the department's experience.

Note. It is not a validated protocol and differs from observed practice (antibiotic therapy in 88.6% of patients, repair in 66.7%). ODB: osteodural breach; CCW: craniocerebral wound.

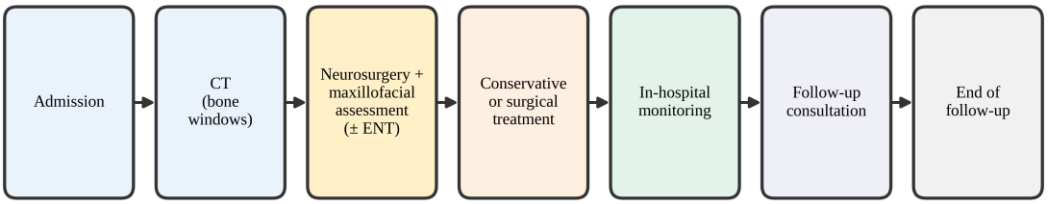


Figure 6. Chronological care pathway of patients with ACFF, from admission to the end of follow-up.

4.8 Robustness of results and uncertainty

With 10 events, all estimates are imprecise, and Firth penalisation does not change this: it reduces bias, not the width of the intervals. The sensitivity analyses and the anatomical score (AUC 0.56) add little information. Only one conclusion is robust: no lesional factor is established as a predictor in this series. Pneumocephalus and evident ODB, whose estimates point in the same direction, remain hypotheses.

5. Strengths and Limitations

This series comprises 114 ACFF, a large number for a rarely reported lesion. A single department, a single team, definitions fixed before the analysis and an explicitly exploratory framework are its other assets.

The limitations are numerous. With 8 fistulas and 2 cases of meningitis, no conventional multivariable modelling was possible; the study could only detect strong associations, and the absence of significance does not exclude clinically plausible links. The composite outcome combines different mechanisms (leak through the breach, contamination via an open depressed fracture) and does not distinguish leaks present at admission from those appearing later. ODB is defined in part by pneumocephalus, CSF leak and operative finding: its association with fistula is therefore partly circular, and so is its association with repair when operative finding enters the definition. No β2-transferrin assay was available, hence a risk of misclassification, especially for transient fistulas that healed before admission.

The analysis rests on the operative register and the institutional database, whose completeness was not verified against source records. The management, broad and uncompared, precludes any inference about the effect of repair, antibiotics or vaccination, since repair may itself prevent the

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outcome studied. Follow-up relied on GOS at a variable interval, missing in 6 patients (5.3%). The attribution of deaths (one of them by sepsis of unspecified source) is clinical and unverified.

5.1 Potential sources of bias

Single-centre recruitment in a tertiary referral centre, which receives referred cases, and the inclusion of only hospitalised patients who underwent CT expose the study to selection bias. The diagnosis of ODB and pneumocephalus, based on neurosurgical interpretation and reports, without independent radiological review or systematic thin slices, exposes it to misclassification bias. Information bias is possible: the database combines a retrospective historical component and a recent component with standardised collection, and we limited the analysis to the latter in order to collect complications homogeneously. The management analyses suffer from confounding by indication, since it is the highest-risk patients who are repaired and treated. Residual confounding by unmeasured variables remains possible. The results may be generalised, with caution, to African centres with a comparable neurosurgical organisation.

6. Key Messages

1. CSF fistula and meningitis were rare (8.8%) and had a good course in this series of 114 ACFF.
2. Management was broad (repair in two patients out of three, antibiotics in nearly nine out of ten) and uncompared: no effect of any of its elements can be inferred.
3. Pneumocephalus and evident ODB, more frequent in patients with a complication without a significant difference, are leads for closer monitoring; ODB partly overlaps pneumocephalus and leak by its definition.
4. A multicentre study, with standardised radiological review and biological confirmation of fistulas, is needed before any clinical use.

7. Perspectives

A multicentre African registry of skull-base trauma would allow numbers to be pooled. It should include standardised radiological review, confirmation of fistulas by β2-transferrin, the date of the leak relative to repair, the reason for each operative decision and each antibiotic prescription, and standardised follow-up of rhinorrhoea.

8. Conclusion

In this West African series of 114 ACFF, CSF fistula and meningitis were rare (8.8% in total) and had a good course. Management was broad, with skull-base repair in two patients out of three and antibiotics in nearly nine out of ten, and uncompared: no effect of these measures can be inferred. No lesional association was significant; pneumocephalus and evident ODB, more frequent in patients with a complication, remain monitoring hypotheses to be tested in multicentre studies. This series provides original descriptive data from sub-Saharan Africa.

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List of abbreviations

ACFF, anterior cranial fossa fracture; ASDH, acute subdural haematoma; CCW, craniocerebral wound; CSF, cerebrospinal fluid; CT, computed tomography; EDH, extradural haematoma; GCS, Glasgow Coma Scale; GOS, Glasgow Outcome Scale; IPH, intraparenchymal haematoma; IQR, interquartile range; ODB, osteodural breach; OR, odds ratio; SAH, subarachnoid haemorrhage; STROBE, Strengthening the Reporting of Observational Studies in Epidemiology.

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Declarations

Ethics approval and consent: The study was conducted in accordance with the principles of the Declaration of Helsinki. The protocol was reviewed and approved by the Institutional Ethics Committee of Bouaké University Hospital (opinion no. CEI/CHU-BKE/138/2026), which granted a waiver of individual consent, justified by the retrospective nature of the study and the exclusive use of anonymised routine records, from which no patient could be identified.

Consent for publication: Not applicable. The manuscript contains no individual data allowing a patient to be identified.

Data availability: Anonymised individual data and the analysis code are available from the corresponding author on reasonable request, in compliance with applicable ethical regulations.

Authors' contributions: All authors contributed substantially to the conception of the study, data collection, analysis and interpretation of the results, or to the drafting and critical revision of the manuscript. All have read and approved the submitted version and collectively accept responsibility for it.

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Conflicts of interest: The authors declare that they have no conflicts of interest.

Reporting compliance: The study is reported in accordance with the STROBE recommendations for observational studies; the completed checklist is provided as supplementary material.

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