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Original Article

Decompressive craniectomy at the National Hospital of Niamey: Prospective study of the epidemioclinical profile, indications, surgical techniques, and results in a context of limited resources

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ABSTRACT

Background: Decompressive craniectomy (DC) is a neurosurgical technique that is gaining renewed interest due to the worldwide resurgence of head injuries. We aimed to analyze the quality of management and prognosis of patients who underwent this surgery in the context of limited resources.

Methods: This was a prospective, longitudinal, descriptive, and analytical study following STROBE, lasting 36 months at the National Hospital of Niamey in patients who had undergone DC. $P \leq 0.05$ was considered significant.

Results: During our study, we collected 74 cases of DC. The mean age was 32.04 years (10–75 years), with male predominance (91.89%). DC was mainly performed following head trauma (95.95%), the main cause of which was road traffic accidents (76%; 54/71). On admission, most patients presented with altered consciousness (95.95%) and pupillary abnormalities (62.16%). The average time between brain damage and brain scan was 31.28 h, with parenchymal contusion being the most frequent lesion (90.54%). The majority of patients (94.59%) underwent decompressive hemicraniectomy. Postoperative complications accounted for 71.62% of all cases, with 33.78% resulting in death. Among survivors, 55.10% had neurological sequelae at the last consultation (27/49). The main factors associated with the risk of death and morbidity were a Glasgow coma score ≤8, pupillary abnormality on admission, the presence of signs of brain engagement, and a long admission delay.

Conclusion: Our study shows that the impact of limited resources on our care is moderate. Future research will concentrate on long-term monitoring, particularly focusing on the psychosocial reintegration of patients post-DC.

Keywords: Craniocerebral trauma, Decompressive craniectomy, Developing countries, Infarction, Intracranial hypertension

INTRODUCTION

Refractory intracranial hypertension (RICH) is the main factor associated with an increased risk of death and/or morbidity in acute brain injury.[14,15,43] At present, decompressive craniectomy (DC) is recognized as the gold standard surgical intervention of last resort for RICH.[4,17,22] DC is a long-standing neurosurgical technique that is experiencing a resurgence of interest due to the worldwide increase in traumatic brain injury (TBI) (69 million/year).[27] The Brain Injury Association of America defines TBI as an impairment of brain function or other evidence of brain injury caused by mechanical force.[37] TBI is a major public health problem, particularly in low-to-middle-income countries, where it places a heavy burden on the healthcare system.[8,39] Road accidents are the leading cause of TBI in developing countries, particularly in sub-Saharan Africa, where almost 90% of global TBI deaths are concentrated (5 million/year).[1,10,27,39] Nevertheless, the indication for DC must be rigorous, as the severity of cerebral lesions and comorbidities greatly influence the postoperative course.[24,27,45]

The management of patients with DC necessitates a multidisciplinary approach. However, this approach faces many challenges at the National Hospital of Niamey (NHN). The main challenges are, first, the absence of universal health coverage to cover the cost of care, which is too high in relation to the average purchasing power of the Niger population. This cost is particularly high due to the need for a second cranioplasty surgery and rehabilitation care.[4] Second, the neurosurgical operating room and equipment do not meet international standards. Third, it is essential to highlight the absence of a neuro-resuscitation unit for the management of massive TBI and of a specialized rehabilitation service for the management of severe disabilities.

Faced with these challenges, we conducted a study at NHN to analyze the quality of management and prognosis of patients with DC and to identify the impact of limited resources, typical of low-to-middle-income countries, on our management.

Context

Niger, with a surface area of 1,267,000 km², is the largest country in West Africa. It is a landlocked country situated between latitudes 11°37 and 23°33 North and longitudes 0°06 and 16° East. It is bordered to the north by Algeria and Libya, to the east by Chad, to the south by Nigeria and Benin, and the west by Burkina Faso and Mali. Administratively, it is subdivided into 8 regions (Agadez, Dosso, Maradi, Tahoua, Tillabery, Zinder, Diffa and Niamey), which are divided into 67 departments. According to the latest data published in December 2022, Niger's population was estimated at 23,591,983. The population is unevenly distributed across the country, with the highest average density in the capital (Niamey), at 5,356.6 inhabitants/km², compared with an average density of 18.6 inhabitants/km² nationwide. The population is also characterized by extreme youth (56.3% are under 15), and over 84% of the population lives in rural areas. The national electrification rate was 17.9%. On the economic front, the primary sector contributes 36.5% of the gross domestic product, which earned it 131st place in the "Doing Business 2021" ranking. On the health front, indicators show insufficient health coverage (53.2%), with 4051 registered health facilities and 1132 practicing doctors, giving a ratio of 20,841 inhabitants per doctor (the World Health Organization standard is one doctor per 10,000 inhabitants). Note that Niger's health policy is mainly focused on the management of infectious diseases (malaria, tuberculosis, hepatitis, pneumonia, acquired immunodeficiency syndrome, etc.), childhood illnesses (infant malnutrition, diarrhea, vaccinations, etc.), and the activities of maternity units.[35,38]

The history of neurosurgery in Niger began with the return of the late Professor SANOUSSI Samuila from Strasbourg to NHN in the late 90s. He was instrumental in establishing the first neurosurgery department (36 beds) and installing the country's first computed tomography (CT) scanner.[6,33] Today, Niger has four neurosurgery departments, with 14 active neurosurgeons, that is, one neurosurgeon for every 1,685,142 inhabitants, half of whom live at NHN, hence the strong referral to this hospital. Multidisciplinary management of neurotrauma patients remains difficult due to the lack of specialized medical staff (five intensive care physicians and one rehabilitation physician for the entire hospital). Only one of the 12 operating rooms is dedicated to neurosurgical activities (emergencies and scheduled surgery), with an average of four to five patients per day. This operating room no longer meets international standards because most cranial flaps are performed the old-fashioned way (using drill bits and a Gigli saw), which significantly increases the operating time. Hemostasis is performed almost exclusively with bipolar forceps due to the recurrent shortage of hemostatic products. The latter, the ventriculoperitoneal shunt kit, and osteosynthesis materials, such as trauma screws and Roy Camille plates, are at the patient's expense. This situation has an impact on the time taken and quality of treatment due to the low purchasing power of the general population.

MATERIALS AND METHODS

Patients and study design

We conducted a prospective, longitudinal, observational, descriptive, and analytical study at NHN following the strengthening of the reporting of observational studies in epidemiology (STROBE) guidelines over 36 months from

October 2020 to October 2023. The neurosurgery, general intensive care, and emergency surgery departments were used as study settings.

This research represents a pilot clinical study of this surgical technique carried out in a neurosurgical department in Niger. For this initial study, we adopted a longitudinal, prospective design with both descriptive and analytical objectives. This methodology was chosen for its ease of implementation in a resource-limited context, particularly given the absence of certain professional roles such as neuroepidemiologists, data managers, clinical research coordinators, etc.

Inclusion and exclusion criteria

All patients admitted to NHN during our study period with a head injury, whether isolated or as part of a polytrauma, cerebrovascular syndrome, or brain tumor, and for whom DC was indicated, were included in our study.

We excluded from the study all patients admitted to NHN during our study period for whom DC was indicated but who:

- Died on the operating table before closure;
- Had unusable data;
- Patients or legal guardians refused to participate in the study.

Judging criteria

The indication for surgery was based on a combination of information derived from the severity of the head injury (initial Glasgow Coma Scale [GCS], pupil status, pupil reactivity to light), time to admission to the surgical emergency department, Marshall's CT score, and the presence of the signs of intracranial hypertension (ICH) intraoperatively. Postoperative assessment was performed according to the last Glasgow Outcome Scale (GOS) measured. The outcome was determined as follows:

- Unfavorable outcome (GOS 1, GOS 2);
- Favorable outcome (GOS 3, GOS 4, and GOS 5).

To standardize our data, we decided not to use the modified Rankin score to assess the postoperative follow-up of patients who underwent DC following malignant middle cerebral artery (MCA) infarction. In addition, we used Marshall's CT score for non-traumatic lesions, even though these scores are not specifically designed for this purpose.

Data collection methodology and software

We initially collected information using a paper questionnaire (epidemiological, clinical, paraclinical, operative, and postoperative data). We then stored and coded this information in a relational database using an input mask developed with Epi-info 7.5.2.0 software. This database was then exported to R × 64 4.3.2 statistical analysis software for descriptive analysis (tabulation and graphing) and univariate regression (logistic or linear). It should be noted that most of these variables were coded in the input mask as dichotomous variables (Yes/No), although some were coded as continuous variables (age, delay, etc.) and categorical variables (mode of admission, reason for admission, etc.).

Statistical analysis plan

Our descriptive analysis considered all variables, and we structured our variable distribution tables as follows:

- Qualitative variables: In numbers (frequency [in %]);
- Quantitative variables: In mean (minimum-maximum).

Due to the lack of a control group and the size of our cohort, we were unable to conduct a robust multivariate regression. Consequently, we performed only univariate regressions during the inferential analysis.

Odds ratios (OR) in the analytical tables were calculated using logistic or linear univariate regression. This regression was performed after Pearson's Chi-square test for comparison of proportions (morbimortality and independent variables) or Student's *t*-test for comparison of means (performance indicators and independent variables). We considered $P \leq 0.05$ significant and calculated their 95% confidence intervals.

For our univariate regression studies, we used all the independent variables contained within our descriptive analysis tables [Tables 1-4] for inferential analysis with our dependent variables (posttraumatic hydrocephalus, postoperative epilepsy, neurological sequelae, and patient mortality). However, in our final univariate regression tables [Tables 5-7], we included only those independent variables that showed a significant association with the dependent variables.

Ethical and administrative considerations

Research authorization was granted by the Dean of the Faculty of Health Sciences of the University of Niamey and the General Manager of NHN on written request. Data were collected after obtaining informed consent from the patients or their legal guardians. Patient anonymity was respected throughout the study.

RESULTS

Descriptive analysis

Epidemiological data

During our study, we recorded 74 cases of DC. The majority of patients, that is, 50% (37/74), were from the Niamey region, followed by the Tillabéri region, which accounted for 21.62% of

Table 1: Distribution of patients according to clinical signs.

Clinical signs	Number of cases (Freq in %)[1]	Total
Altered state of consciousness	71 (95.95)	74
Intracranial hypertensive syndrome	60 (81.08)	74
Glasgow coma scale		
(13–15)	5 (6.76)	74
(3–8)	46 (62.16)	
(9–12)	23 (31.08)	
Psychomotor agitation	45 (60.81)	74
Seizures	39 (52.70)	74
Initial loss of consciousness	13 (17.57)	74
Trauma to the cranial nerves	2 (2.70)	74
Hemibody neurologic deficit	26 (35.14)	74
Aphasia posttraumatic	3 (4.05)	74
Pupillary light reflex		
Abnormal	46 (62.16)	74
Normal	28 (37.84)	
Abnormal pupillary responses		
Anisocoria	22 (47.83)	46
Bilateral miosis	10 (21.74)	
Bilateral mydriasis	14 (30.43)	
Palpebral conjunctival color of the eyes		
Normal	66 (89.19)	74
Pallor	8 (10.81)	
Hemodynamic and ventilatory status		
Instability	24 (32.43)	74
Stability	50 (67.57)	
Neurovegetative disorder	9 (12.16)	74

[1]*n* (%)

Table 2: Distribution of patients according to lesions on preoperative cerebral CT.

Lesions on cerebral CT scan	Number of cases (Freq in %)	Total
Parenchymal brain contusion (%)	67 (90.54)	74
Acute subdural hematoma (%)	54 (72.97)	74
Extradural hematoma (%)	17 (22.97)	74
Posttraumatic pneumocephalus (%)	9 (12.16)	74
Intraparenchymal hematoma (%)	16 (21.62)	74
Subarachnoid hemorrhage (%)	62 (83.78)	74
Intraventricular hemorrhage (%)	17 (22.97)	74
Cerebral edema (%)	63 (85.14)	74
Cerebral ischemia (%)	7 (9.46)	74
Hydrocephalus (%)	1 (1.35)	74
Brain engagement (%)	31 (41.89)	74
Marshall CT classification (%)		74
III	44 (59.46)	
IV	21 (28.38)	
II	5 (6.76)	
VI	4 (5.41)	
Cranial vault fracture (%)	38 (51.35)	74
Skull base fracture (%)	26 (35.14)	74
Time between brain damage and brain CT scan (in hours)	31.28 (0.00–220)	74

CT: Computed tomography

Table 3: Distribution of patients according to indication and therapeutic data.

Indications and therapeutic data	Number/Mean (Freq/Min-Max)	Total
Surgical indication (%)		74
Hemicraniectomy	70 (94.59)	
Bifrontal craniectomy	3 (4.05)	
Suboccipital decompression	1 (1.35)	
Removal of the large bone flap (%)	69 (93.24)	74
Lost bone craniectomy (%)	5 (6.76)	74
Surgical debridement (%)	4 (5.41)	74
Intraoperative appearance of the brain parenchyma (%)		74
Hyperemic and bruised	29 (39.19)	
Hyperemic	26 (35.14)	
Edema	17 (22.97)	
Brain mush	2 (2.70)	
Tumor excision (%)	1 (1.35)	74
Corticotomy and hematoma evacuation (%)	5 (6.76)	74
Durotomy-duroplasty (%)	73 (98.65)	74
Ventriculoperitoneal shunting (%)	1 (1.35)	74
Replacing the cranial flap (%)	10 (13.51)	74
Bone flap preservation in the abdominal wall (%)	59 (79.73)	74
The type of decompression (%)		74
Prophylactic	49 (66.22)	
Secondary	25 (33.78)	
Time between brain damage and surgery (in hours)	49.75 (4.00–230)	72
Duration of surgery (in minutes)	133 (4.00–280)	74
Direct cost of care (in USD)	636.15 (0.00–1391,55)	74

patients (16/74) [Figure 1]. Patients from other regions accounted for 28.38% (21/74). The average age was 32.04 years, with extremes ranging from 10 to 75 years, and the 20–30 age group was the most represented, at 36.5% (27/74). The average admission time to the surgical emergency department was 28.97 h, with extremes ranging from < 1h to 216 h. The majority of the patients, constituting 59.5% (44/74), were admitted <8 h after the brain damage. Male patients predominated, accounting for 91.89% of the cases (68/74). The majority of our patients, 95.94% (71/74), had suffered a head injury, 2.70% had suffered a stroke (2/74), and 1 patient (1.35%; 1/74) had been treated for a brain tumor. Among head injuries, 77.46% (55/71) were isolated head injuries, and 22.54% were polytrauma cases (16/71). Road traffic accidents were the main cause of head injuries, accounting for 76.1% (54/71), followed by assaults (15.5%; 11/71) and falls (8.5%; 6/71).

Clinical presentation

On admission, the altered consciousness was the predominant functional sign (95.95%; 71/74). The majority of patients were admitted with a GCS ≤8, that is, 62.16%

Table 4: Distribution of patients according to postoperative course data.

Postoperative follow-up	Number/Mean (Freq/Min-Max)	Total
Postoperative course (%)		74
Complicated	53 (71.62)	
Simples	21 (28.38)	
Postoperative reception service (%)		74
General intensive care	37 (50.00)	
Emergency recovery room	34 (45.95)	
Morgue	3 (4.05)	
Duration of stay in the intensive care unit (in days)	8 (1.00–22)	37
Postoperative outcome (%)		74
Favorable	49 (66.22)	
Unfavorable	25 (33.78)	
Neurological sequelae (%)	27 (36.49)	74
Postoperative neurological deficit (%)	6 (8.11)	74
Surgical site infection (%)	4 (5.41)	74
Postoperative meningitis (%)	8 (10.81)	74
Cranioplasty infection (%)	3 (10.81)	37
Post-craniectomy infection (%)	10 (13.51)	74
Postoperative epilepsy (%)	23 (31.08)	74
Postoperative hydrocephalus (%)	3 (4.05)	74
The last GOS measured (%)		74
5	45 (60.81)	
1	25 (33.78)	
3	3 (4.05)	
4	1 (1.35)	
Death of the patient (%)	25 (33.78)	74
Time between Surgery and death (in days)	8.24 (1.00–64)	25
Hospital stays (in days)	24 (1.00–210)	74

GOS: Glasgow outcome scale

(46/74), 31.08% of patients had GCS scores between 9 and 12 (23/74), and 6.76% had GCS scores between 13 and 15 (5/74). An ICH syndrome was noted in 81.08% of patients (60/74). More than half of our patients (62.16%; 46/74) had abnormal pupillary responses, with anisocoria predominating (47.83%; 22/46). In most patients, 89.19% (66/74) palpebral conjunctival color was normal. Patients with hemodynamic and ventilatory instability on admission accounted for 32.43% (24/74) [Table 1].

Preoperative CT data

Our patients underwent a preoperative cerebral CT scan after an average of 31.28 hours. The most frequent CT scan lesion was parenchymal brain contusion, accounting for 90.54% of cases (67/74), followed by cerebral edema, 85.14% (63/74), subarachnoid hemorrhage, 83.78% (62/74), and acute subdural hematoma (SDH), 72.97% (54/74) [Table 2].

Treatments characteristics

The majority of our patients, 94.59% (70/74), underwent decompressive hemicraniectomy. After durotomy, the brain parenchyma was predominantly hyperemic in 74.33% (55/74) of the patients. The flap was restored in 13.51% (10/74). Surgery was performed an average of 49.75 hours after the incident and lasted an average of 133 min. The direct cost of care averaged $636.15, that is, 393,150 FCFA (the XOF/USD exchange rate of 618.0169, which was recorded on October 30, 2023, the end of the study) [Table 3].

Postoperative follow-up

Half of our patients (50%; 37/74) were taken directly to the intensive care unit after surgery, with an average stay of 8 days. A postoperative CT scan was performed in 51.35% of patients (38/74). Among these patients, 55.26% (21/38) experienced postoperative cerebral ischemia, 34.21% (13/38) developed postoperative subdural hygroma, 34.21% (13/38) had postoperative ventriculomegaly, and 7.89% (3/38) suffered from postoperative hydrocephalus. Notably, most of the latter required a ventriculoperitoneal shunt (66.67%; 2/3) [Figure 2]. The postoperative course was complicated in most patients, that is, 71.62% (53/74) [Table 4]. The most frequent postoperative complications were neurological sequelae (36.49%; 27/74), postoperative epilepsy (31.08%; 23/74), postoperative meningitis (10.81%; 8/74), and surgical site infection (5.41%; 4/74). We recorded 33.78% deaths (25/74), occurring on average 8.24 days after surgery. Cranioplasty was performed in 75.51% of patients (37/49), with an average delay of 73 days. Although postcranioplasty operative follow-up was generally straightforward, 10.81% of cases (4/37) required surgical revision (4/37), and in 2.70% of cases, this resulted in death (1/37). The overall outcome was favorable in 66.22% of cases (49/74) [Figure 3]. A significant proportion of survivors, representing 55.10% of cases (27/49), retained neurological sequelae, necessitating ongoing rehabilitation. Among these sequelae, we reported 77.78% frontal syndrome (21/27), 48.14% residual motor deficit (13/27), 37.03% aphasia (10/27), 3.70% dysarthria (1/27), 51.85% memory disorders (14/27), and 11.11% posttraumatic optic neuropathy (3/27). It is important to note that these symptoms presented a challenging prognosis due to the lack of specialized rehabilitation, resulting in a high failure rate among survivors with residual motor deficits (40%; 4/10), three of whom unfortunately passed away. Cases of posttraumatic optic neuropathy showed promising progress following brief, intensive corticosteroid therapy. Survivors with postoperative epilepsy (55.1%; 27/49) were systematically treated with readily available anti-epileptic drugs for a minimum of 6 months (Sodium

Table 5: Results of the binary univariate logistic regression analysis of predictors of death.

Independent variables	Death	OR[1]	CI[1]	*P*-value
Reason for admission	25			**0.001**
Stroke		1.00	—	
Polytrauma		3.00	0.10–89.1	0.472
Isolated head injuries		0.28	0.01–7.40	0.379
Brain tumor		0.00		0.991
Initial GCS score	25			**<0.001**
(9–15)		1.00	—	
(3–8)		13.0	3.35–86.7	**0.001**
Hemibody neurologic deficit	25			**0.031**
No		1.00	—	
Yes		3.00	1.10–8.41	**0.033**
Pupillary light reflex	25			**<0.001**
Normal		1.00	—	
Abnormal		7.64	2.27–35.3	**0.003**
Hemodynamic and ventilatory status	25			**<0.001**
Stability		1.00	—	
Instability		12.8	4.20–43.6	**<0.001**
Brain engagement	25			**0.024**
No		1.00	—	
Yes		3.09	1.16–8.63	**0.027**
Direct cost of care	25	0.99	0.99–1.00	**<0.001**

Binary Univariate Logistic Regression: Deaths/Study Variables. [1]OR: Odds ratio, CI: Confidence interval, GCS: Glasgow coma scale, Bold values: *P*-value ≤ 0.05

Table 6: Results of the binary univariate logistic regression analysis of predictors of postoperative epilepsy.

Independent variables	Epilepsy	OR[1]	CI[1]	*P*-value
Seizures	23			**0.002**
No		1.00	—	
Yes		5.14	1.75–17.6	**0.005**
Psychomotor agitation	23			**<0.001**
No		1.00	—	
Yes		14.1	4.43–50.9	**<0.001**
Post-craniectomy infection	23			**0.006**
No		1.00	—	
Yes		7.00	1.73–35.6	**0.009**
Postoperative cerebral ischemia	23			**<0.001**
No		1.00	—	
Yes		9.78	3.20–33.0	**<0.001**
Postoperative subdural hygroma	23			0.059
No		1.00	—	
Yes		3.28	0.96–11.7	0.058
Neurological sequelae	23			**<0.001**
No		1.00	—	
Yes		41.9	11.1–216	**<0.001**
Direct cost of care	23	1.00	1.00–1.01	**0.018**

Binary Univariate Logistic Regression: Epilepsy/Study Variables.
[1]OR: Odds ratio, CI: Confidence interval, Bold values: *P*-value ≤ 0.05

Valproate and/or phenobarbital), which were discontinued as soon as no electrical signs were seen on the follow-up electroencephalogram. Patients with meningitis received empirical antibiotic therapy, later tailored to the identified pathogens. Two instances of infection occurred in relation to the ventriculoperitoneal shunt, necessitating surgical revision, one of which (50%; 1/2) unfortunately resulted in the patient's demise.

Inferential analysis

Variables associated with death

The main variables with a statistically significant association with an increased risk of death were as follows: GCS <9 (OR = 13; $P = 0.001$), hemodynamic and ventilatory instability (OR = 12.8; $P < 0.001$), and abnormal pupillary responses (OR = 7.64; $P < 0.001$) [Table 5].

Variables associated with the risk of postoperative epilepsy

The main variables with a statistically significant association with an increased risk of postoperative epilepsy were as follows: neurological sequelae (OR = 41.9; $P < 0.001$), postoperative subdural hygroma (OR = 3.28; $P = 0.022$), and postoperative cerebral ischemia (OR = 9.78; $P < 0.001$) [Table 6].

Table 7: Results of the binary univariate logistic regression analysis of predictors of posttraumatic hydrocephalus.

Independent variables	Hydrocephalus	OR[1]	CI[1]	*P*-value
Postoperative meningitis	3			**0.012**
No		1.00	—	
Yes		26.4	2.18–632	**0.012**
Cranioplasty infection	3			**0.001**
No		1.00	—	
Yes		140	7.97–6,117	**0.002**
Surgical site infection	3			0.118
No		1.00	—	
Yes		11.3	0.45–160	0.074
Postoperative aphasia	3			**0.028**
No		1.00	—	
Yes		15.8	1.36–363	**0.031**
Direct cost of care	3	1.01	1.00–1.02	**0.029**
Postoperative cerebral ischemia	3			**0.005**
No		1.00	—	
Yes		387,144,674	0.00–NA	0.996

Binary univariate logistic regression: Hydrocephalus/Study variables. [1]OR: Odds ratio, CI: Confidence interval, Bold values: *P*-value ≤ 0.05

Table 8: Results of the binary univariate logistic regression analysis of predictors of postoperative neurological sequelae.

Independent variables	Sequelae	OR[1]	CI[1]	*P*-value
Seizures	27			**0.020**
No		1.00	—	
Yes		3.21	1.20–9.17	**0.024**
Intraparenchymal hematoma	27			**0.016**
No		1.00	—	
Yes		4.02	1.29–13.5	**0.019**
Replacing the cranial flap	27			0.104
No		1.00	—	
Yes		3.07	0.79–13.1	0.108
Bone flap preservation in abdominal the wall	27			0.135
No		1.00	—	
Yes		0.42	0.13–1.32	0.135
Postoperative cerebral ischemia	27			**<0.001**
No		1.00	—	
Yes		8.54	2.84–28.7	**<0.001**
Postoperative ventriculomegaly	27			**<0.001**
No		1.00	—	
Yes		19.4	3.24–372	**0.007**
Postoperative subdural hygroma	27			**0.008**
No		1.00	—	
Yes		5.38	1.54–22.0	0.011
Postoperative epilepsy	27			**<0.001**
No		1.00	—	
Yes		41.9	11.1–216	**<0.001**
Psychomotor agitation	27			**<0.001**
No		1.00	—	
Yes		131	22.3–2,556	**<0.001**

Binary univariate logistic regression: Neurological sequelae/Study variables
[1]OR: Odds ratio, CI: Confidence interval, Bold values: *P*-value ≤ 0.05

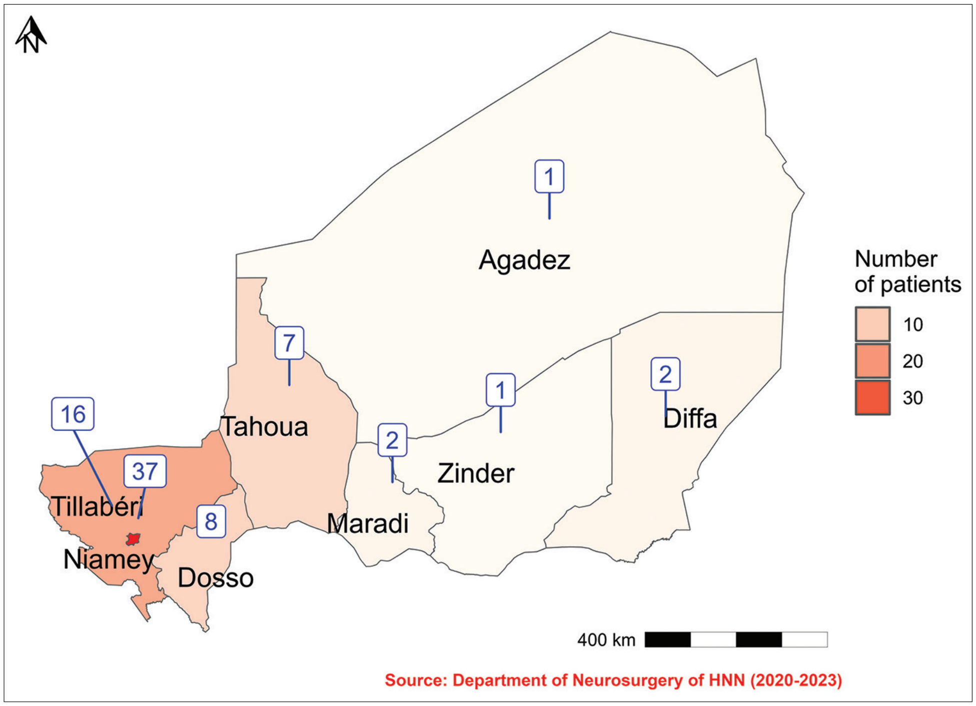

Figure 1: Distribution of patients by trauma location.

Variables associated with the risk of posttraumatic hydrocephalus

The main variables with a statistically significant association with an increased risk of posttraumatic hydrocephalus were as follows: postoperative meningitis (OR = 26.6; $P < 0.012$) and cranioplasty infection (OR = 140; $P = 0.002$) [Table 7].

Variables associated with the risk of posttraumatic neurological sequelae

The main variables with a statistically significant association with an increased risk of neurological sequelae were as follows: postoperative epilepsy (OR = 41.9; $P < 0.001$) and postoperative ventriculomegaly (OR = 19.4; $P = 0.007$) [Table 8].

DISCUSSION

Epidemiological data

In our study, 74 cases of DC were performed, mainly for TBIs (94.94%), the main cause of which was road traffic accidents (76.1%). The average age was 32.04 years, and the majority were male (91.89%). It is important to emphasize that the TBI situation in Niamey is alarming. Over 4000 cases were recorded during our study in the surgical emergency department of NHN alone, one of the city's three national hospitals (1,365,927 inhabitants).[35] However, the similarity between the epidemiological data of the present study and those of previous studies conducted in NHN on TBI highlights the endemic nature of this problem.[25,44] TBI is also a major public health problem worldwide, with a global incidence of approximately 69 million per year.[41] Their impact is significant in low-to-middle-income countries, where 75% of cases and two-thirds of deaths are concentrated, mainly in the working population, placing a considerable burden on the health-care system.[41] In Niger, where this working population represents 47.8% of the 23,591,981 inhabitants in 2022, we infer a fairly significant impact on the country's economy, despite the absence of studies to corroborate this impact.[35] The epidemioclinical profile of patients with TBI in Niamey mirrors that of the population in most studies conducted in low-to-middle-income countries. These studies reveal a recrudescence of TBI, mainly related to traffic accidents, and a predominance of young (20–40 years) male adults (70–90%).[1,41,47,49] In Sahelian countries, this upsurge can be explained by several factors. First, the increase in the incidence of road traffic accidents due to the explosion in the number of cars on the road, coupled with the poor condition of roads and poor driving habits. Second, the emergence of armed conflicts in the Sahel has increased the incidence of ballistic injuries.[1,41] In light of this distressing reality, it becomes essential to propose targeted public health strategies for prevention in Niger, such as initiating road safety campaigns, advocating for helmet usage, and educating drivers. These road safety campaigns should specifically target young adults, who are more prone to risky driving. The implementation of these measures could

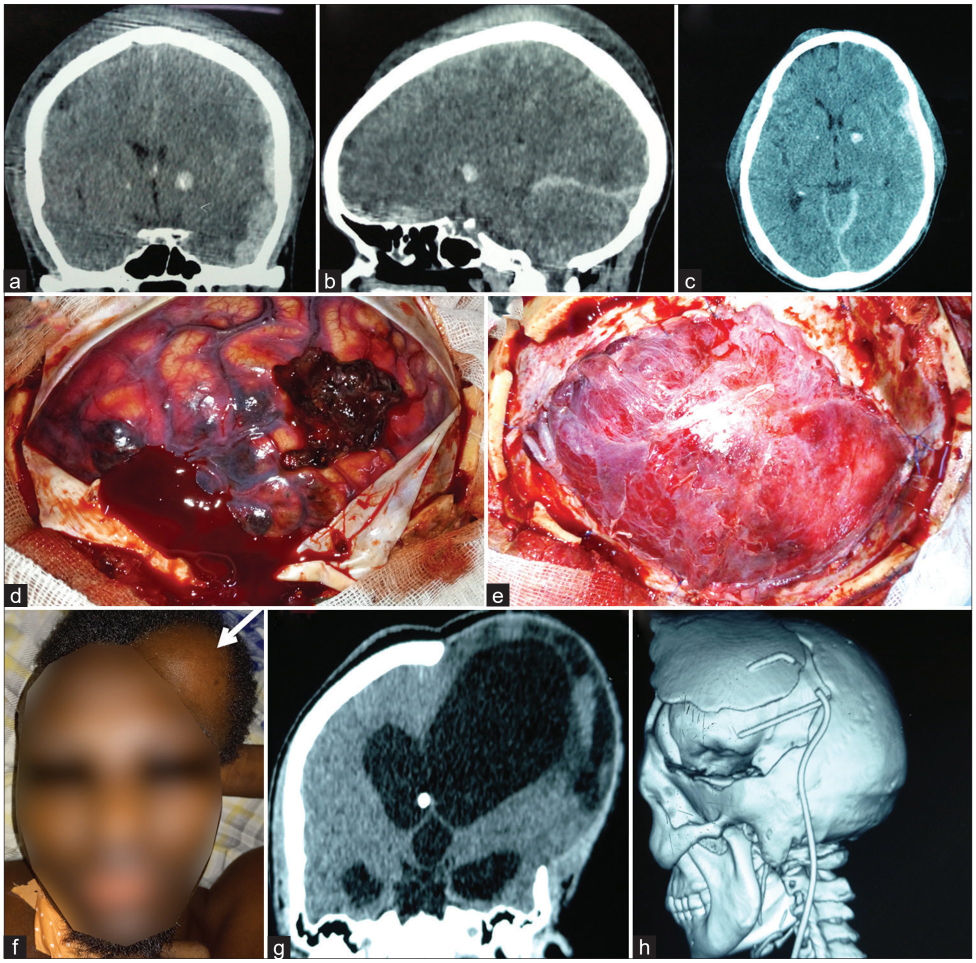

Figure 2: Iconograms of a 20-year-old patient who underwent decompressive craniectomy following a road traffic accident resulting in severe head trauma, the operative sequelae of which were complicated by major hydrocephalus. (a-c) Preoperative computed tomography images showing diencephalic contusions, acute subdural hematoma, and subarachnoid hemorrhage; (d and e) Intraoperative images showing cerebral contusions and duroplasty; (f) Late postoperative frontal photograph showing distension opposite the cranial flap (white arrows); (g and h) Postoperative control computed tomography images showing tetraventricular hydrocephalus with disconnection of the ventriculoperitoneal shunt.

potentially decrease the prevalence of head injuries, especially those associated with road accidents, and alleviate the strain they impose on our nation's healthcare systems.

Admission time

Several scientific studies have demonstrated a correlation between admission time and mortality. In Tau *et al*., patients with a delay of more than 7 h had less favorable outcomes.[48] A similar conclusion was reached by Di *et al*., who reported that a long delay had a negative impact on postoperative results.[7] In our study, although 84% of Niger's population lives in rural areas, most of our patients were injured in urban areas.[35] However, although the admission time during our study was comparable to that of Tau *et al*., we observed higher morbidity.[48] These findings highlight the importance of training basic neurosurgical healthcare personnel to promptly identify and expedite the transfer of severe head injuries during the pre-hospital phase. It is, therefore, essential to promote the training of all specialists involved in the treatment of patients with severe head injuries. These include neurosurgeons, anesthetists, intensive care specialists, rehabilitation physicians, and nursing staff. It is also crucial to allocate resources toward improving healthcare infrastructure, which includes the development of neurosurgical facilities and the establishment of training programs for local healthcare professionals. Furthermore, efforts should be directed toward improving the health transport system in Niger, particularly by increasing

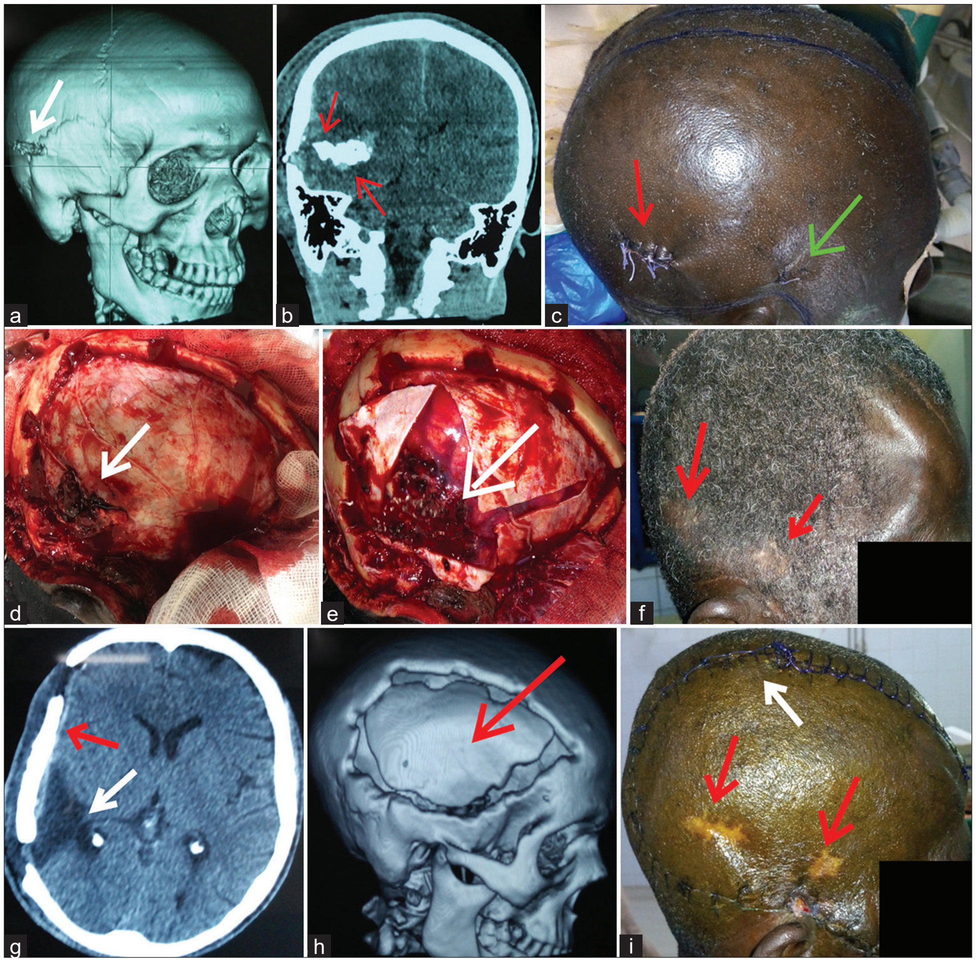

Figure 3: Iconograms of an adult patient who underwent decompressive craniectomy following a ballistic craniocerebral wound from firearm assault, with a favorable postoperative outcome. (a and b) Preoperative computed tomography (CT) images showing the tangential point of impact of the bullet (white arrow), a punch fracture and a focus of edematous-hemorrhagic contusion with intra-parenchymal bone fragments (red arrows); (c) Photograph in the operating room after the patient had been placed on the operating table, shaved and the incision line marked, showing the entrance wound (green arrow) and the exit wound (red arrow); (d and e) Intraoperative images after wide cranial flap, showing dural breach and focus of brain parenchyma mortification after durotomy (white arrow); (f) Photograph of patient 3 months after decompression surgery, showing healed wounds (red arrows); (g and h) Control CT images showing a large area of parieto-occipital ischemia (white arrow) and the cranial flap after cranioplasty (red arrows); (i) Photograph of the patient after cranioplasty, showing healed bullet entry and exit wounds (red arrows) and the healing wound from the second surgery (white arrow).

the number of ambulances available to the population, which currently stands at 467.[39] Such an initiative has the potential to decrease admission times, thereby improving the prognosis of patients with severe head trauma.

Surgical technique

DC is an ancient neurosurgical technique based on Monro-Kellie's law. It consists of performing a large cranial flap followed by an enlarging duroplasty, thereby increasing cranial volume, reducing intracranial pressure (ICP), and avoiding secondary cerebral aggression and encephalic involvement.[4,17] DC has evolved over the centuries, although uncertainty persists as to the first surgeon to perform it. The first known written account of this decompressive surgery was by Annandale in 1894, but it was Thomas Kocher who first used it in 1901 to treat RICH.[2,17,20,50] In 1905, Cushing published a detailed report on subtemporal and suboccipital decompression to relieve RICH in patients with inoperable brain tumors.[5] DC lost popularity during the 1970s due to disappointing results. However, renewed interest in DC was observed in 1980 after the work of Gerl and Tavan,[16] who reported a reduction in mortality from 100% to 70% after bilateral DC following a gunshot wound.[30] At the international expert consensus meeting on the role of DC in treating severe TBI, held in Cambridge on September 28–29, 2017, several recommendations were issued to improve its indications.[27] At present, the type of surgical decompression depends on the anatomical location and the extent of the intracranial lesions. Hemicraniectomy (unilateral frontotemporoparietal DC) is indicated when the lesions are concentrated on one hemisphere. Bifrontal DC and bilateral frontotemporoparietal DC are performed when the lesions are located at the frontal poles. Finally, suboccipital DC is indicated when the lesions are located in the posterior cerebral fossa.[12,27,30,32] Today, primary and secondary DC are considered distinct entities. The unilateral frontotemporoparietal DC is the most commonly used because it creates sufficient space for cerebral edema and relieves pressure on the brainstem. However, bifrontal DC is no longer recommended due to the increased risk of neurological complications and has been replaced by bilateral frontotemporoparietal DC.[48] In our study, hemicraniectomy was performed predominantly (94.59%), whereas bifrontal craniectomy (4.05%) and posterior fossa craniectomy (1.35%) were rarely performed. These results are similar to those of many studies from low-to-middle-income countries, such as Tau *et al*. (hemicraniectomy 92%, bifrontal DC 3%, and suboccipital DC 2%).[48] Recent research indicates that the surgical outcomes of patients undergoing DC are improved when a basal cisternostomy is performed as a coadjuvant treatment.[11,18]

Surgical indications

At present, RICH related to TBI is the main indication for DC. In settings with limited resources and a lack of institutional facilities to provide adequate care, DC is sometimes used as a first-line treatment despite postoperative complications due to the high incidence (around 70%) of ICH in TBI.[12,30,41,45] The latter is responsible for 40–60% of morbidity and mortality, justifying the indication of DC as soon as ICH becomes refractory.[12] In the randomized evaluation of surgery with craniectomy for uncontrollable elevation of ICP (RESCUEicp) trial, RICH was defined as ICP >25 mmHg for at least 1 h. The results of this study were very encouraging, with a significant reduction in mortality after DC of 26.9% versus 48.9% for the control group.[28,48] Primary DC or prophylactic DC is mainly performed to combat postcraniotomy ICH, mainly for acute SDH. However, according to some studies, the results of primary DC for HSAD seem similar to those of craniotomy. Secondary DC is indicated for RICH, which is now defined as ICP >20–25 mm Hg for more than 30 min.[27,32] In our study, DC was mainly indicated for TBI (95.95%). However, continuous ICP monitoring was not performed in our study. Our indications were based on the extent of intracranial lesions (Marshall score), state of consciousness on admission, and evolutionary potential of the lesions. Our decompression surgery was mainly prophylactic (66.22%). These were mainly patients with acute SDH for whom craniotomy was initially indicated and in whom uncontrolled intraoperative cerebral edema prevented the reshaping of the cranial flap. This situation was also reported in the RESCUEicp trial.[28]

Malignant infarction of the MCA accounts for 10–15% of strokes. They cause massive cerebral edema and severe neurological deficits. DC can prevent fatal outcomes. Most patients (71.4% of cases) showed functional improvement after 6 months.[9] However, in our study, we recorded a mortality rate of 50% (1 in 2 cases).

Mortality

In South Africa, DC reduces mortality from severe DC by 90–50%.[48] In our study, overall mortality after DC was similar to that in developing countries, at 35–65%.[17,45,46,48] However, in developed countries, this mortality rate is lower, at 21.9% (RESCUEicp).[28] In the literature, the main risk factors for mortality are accidents involving less protected users, long admission times, advanced age, nonreactive pupils, effacement of the basal cisterns, intraoperative hypotension, and coagulation disorders.[8,32] In contrast, in our study, the main factors significantly associated with a risk of death were GCS score ≤8, pupillary anomaly on admission, hemodynamic and ventilatory instability on admission, hemicorporal deficits on admission, and polytrauma. Most of these factors worsen as the time to admission increases. A reduction in mortality and morbidity can only be achieved by managing all aspects of the pre-hospital system, such as basic neurosurgical healthcare personnel and the medical evacuation system. However, strategies to optimize limited resources, such as developing streamlined protocols for postoperative care and identifying cost-effective alternatives for essential surgical equipment, also play a role in managing postoperative morbidity and mortality.

Postoperative epilepsy

Postoperative epilepsy is characterized by the onset of one or more convulsive seizures at least 1 week after a TBI, requiring antiepileptic treatment.[7,40] With the increase in TBI, seizures have become a challenge due to their adverse effects on cognitive function and high incidence after severe TBI (10–50% of cases).[21] Their pathophysiology is not yet fully understood. However, the risk of this disease increases mainly with the severity of CT, extreme age (especially under 2 years), certain brain regions (especially temporal), posttraumatic amnesia, the presence of early seizures, craniocerebral wounds, and certain medical histories (epilepsy, drug use.).[3,13] In the study by Huang *et al.*, the post-DC acute seizure rate was 10.8%, with over 90% of acute seizures occurring within the first 3 days after DC, and most seizures were focal.[26] Therefore, antiepileptic prophylaxis is recommended to prevent posttraumatic seizures. Phenytoin and sodium valproate are no longer recommended for the prevention of late postoperative epilepsy. However, phenytoin, levetiracetam, and carbamazepine have been shown to reduce seizures during the 1st week after severe CT significantly, but this antiepileptic effect disappears after longer periods.[13,36,40] In our study, we systematically instituted sodium valproate anticonvulsant therapy due to the limited availability of phenytoin; however, we recorded a postoperative epilepsy rate of 31.08%. In our study, neurological sequelae and postoperative ischemia were statistically associated with postoperative epilepsy.

Postoperative hydrocephalus

Postoperative hydrocephalus is defined as dilatation of the cerebral ventricles (Evans index >0.3) after DC.[7,42] It must be distinguished from simple ventriculomegaly, which is a frequent and benign complication (40–45% of cases).[29] It is caused by an obstruction or defect in cerebrospinal fluid (CSF) absorption following aseptic inflammation secondary to the presence of blood or its degradation products.[17,42] The number of cases of hydrocephalus increases significantly after DC, sometimes necessitating ventriculoperitoneal shunting.[12,34,42] Several factors predispose patients to this complication, including subdural hygromas, low initial GCS, very high ICP before DC, anisocoria before DC, significant midline deviation, extreme age (<2 years and over 65 years), the proximity of DC (<2.5 cm) to the anatomical midline, delayed cranioplasty (>3 months), intraventricular hemorrhages, and acute SDH.[12,34] Early diagnosis and treatment are necessary to avoid neurological complications.[19,31] In the literature, this complication is associated with a poor prognosis in over 65% of cases.[19,31] In our study, we recorded 4.08% of postoperative hydrocephalus cases; postoperative infections were statistically associated with this complication, and 33.33% of cases resulted in patient death.

Postoperative infection

Major complications of surgical wounds after DC or cranioplasty include dehiscence, ulceration or necrosis, and infection.[21] In our study, we recorded 5.41% surgical site infections, which is close to the results reported in the literature, that is, 5–19.8% of cases.[27,45] On the other hand, we recorded a higher rate of postoperative encephalic infections (10.81% of cases) than in most scientific studies, that is, 1.5–6%. The intensive use of our operating room can explain this observation.[7,31,48] The incidence of meningitis and ventriculitis is 4%, probably due to an increased risk of CSF leakage. Early detection by looking for signs of meningeal irritation and CSF analysis by monitoring lumbar puncture are recommended.[21] Infection is the leading cause of death in patients with DC, accounting for 60–75% of cases.[46] In our study, infections increased the risk of death seven-fold.

Postoperative neurological sequelae

In low-to-middle-income countries, TBI mainly affects the working population (aged 15–64). In Niger, this age group will represent 47.8% of the population in 2022.[35] Managing the neurological consequences of these traumas has a significant economic impact. Indeed, a large proportion of young working people (76% of cases) work in the informal sector and have no access to social security.[35] Our study revealed that 55.10% of patients had neurological sequelae. Postoperative ventriculomegaly (OR = 23.3; $P < 0.001$) and postoperative epilepsy (OR = 22.3; $P < 0.001$) were associated with an increased risk of this complication. These results are comparable to those of numerous studies conducted in the general population, which estimate the proportion of neurological sequelae to be between 25% and 60%.[7,28,45,46,48] In the literature, factors associated with long-term morbidity include advanced age, low initial GCS, effacement of the basal cisterns, presence of coagulopathy, intraoperative hypotension, and postoperative complications such as hydrocephalus, subdural effusion, and paradoxical hernia.[8,32] This postoperative morbidity prolongs the hospital stay; in the study by Sy *et al.*, the stay was extended for up to 80 days in some patients.[46] The acute consequences of TBI account for only about half of the total burden, with long-term sequelae of particular concern, especially in adolescents and young adults with developing brains (neuroendocrine, neuropsychiatric, and psychosocial sequelae).[30] In addition to mortality during the acute phase, TBI is associated with a risk of death up to 7 times higher during the 13 years following injury and with an overall reduction in life expectancy. The medical community now considers TBI to be a chronic disease, which explains the term "silent epidemic."[41]

Prognostics factors

The GCS was measured after resuscitation, with studies showing a linear relationship between GCS and poor prognosis.[49] An initial GCS ≤8 is universally recognized as an indicator of poor prognosis, with particular attention paid to the motor aspect. According to Silva *et al.*, a short admission time improved outcomes in comatose patients, underlining the importance of early DC in the management of severe TBI.[45] In our study, being in a comatose state (GCS ≤8) increased the risk of death by a factor of 13.

Despite a higher frequency of postoperative complications such as hydrocephalus and epilepsy, mortality in children is lower after DC.[36] Some studies conducted in the general population reveal that patients over 65 years of age have a less favorable prognosis (OR = 24.114).[22,45,47] Authors from sub-Saharan Africa, such as Hamma *et al*. and Purcell *et al*., have found better outcomes in children, regardless of the cause of DC, including gunshot wounds.[23,41] We believe that these results are not only attributable to children's greater resilience to trauma but also to the priority given to the latter children (free care).[35] In our study, we failed to establish a correlation between age and morbidity and mortality.

Limitations of our study

Our study has several limitations. First, being an observational, longitudinal, prospective, and monocentric study carried out with a modestly sized population (<100 cases), it is complex to avoid certain biases inherent in the absence of a randomization process. Second, our study population is non-homogeneous because it includes patients with traumatic, tumor, and vascular brain lesions, and the evolution of these lesions is not necessarily superimposable. Third, our management protocol does not meet international standards, notably regarding systematic orotracheal intubation of all comatose patients (GCS <9/15), continuous ICP monitoring perioperatively, and successive follow-up brain CT scans immediately postoperatively. This situation stems from human and material resource constraints in relation to patient flow. The absence of a control group (sufficiently robust data) and the short duration of postoperative follow-up (<10 years) did not allow us to reach a sufficiently high level of evidence to draw up the first guidelines for cranial trauma in Niger. Further studies are therefore needed to collect sufficient data to adapt international neurosurgical guidelines to the realities of low- and middle-income countries. This adaptation of international guidelines will allow us to establish guidelines for neuro traumatology in Niger and sub-Saharan Africa, where the incidence could rise to 14 million per annum by 2050.[1]

CONCLUSION

Our study shows that DC is mainly performed at the NHN for TBIs. TBI remains a major public health problem, particularly in low-to-middle-income countries such as Niger. Our study demonstrates the efficacy of DC as a therapeutic measure for RICH in the context of limited resources, as the impact was moderate and the operative sequelae of our patients were generally favorable. Future studies will focus on long-term patient monitoring, emphasizing quality of life, successful rehabilitation, and psychosocial reintegration post-DC. This data will help us identify areas of care that need improvement beyond the acute surgical phase. We must also advocate for increased funding from policymakers to conduct multicenter studies to collect enough data for the adaptation of international neurosurgical guidelines to fit the realities of low-to-middle-income countries.

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Ethical approval

The Ethics Committee of the National Hospital of Niamey approved the conduct of this study (Approval No. 00224/DG/HNN/DAF/SGRH, dated October 14, 2023).

Declaration of patient consent

The authors certify that they have obtained all appropriate patient consent.

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Nil.

Conflicts of interest

There are no conflicts of interest.

Use of artificial intelligence (AI)-assisted technology for manuscript preparation

The authors confirm that there was no use of artificial intelligence (AI)-assisted technology for assisting in the writing or editing of the manuscript and no images were manipulated using AI.

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