ORIGINAL ARTICLE

Epidemiologic analysis and mortality outcome of firearm injuries in French Guiana (2016–2019)

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Abstract

Background French Guiana (FG) is a French territory located in South America with the highest rate of armed assaults. FG presents a poorly developed road system and a young and precarious population that makes the geographical and socio-demographic characteristics specific. No data concerning the firearm injury management are available in this country. Studying thesis trauma could permit to improve the management of victims. The objective of this study is to investigate the epidemiology of firearm injuries in FG, to define characteristics of the victims, and to assess factors associated with death. These identified factors could enable target primary prevention and intensification of medical management.

Methods From January 2016 to December 2019, we conducted a retrospective study at the Cayenne General Hospital (CGH), including all patients admitted for firearm injuries in the emergency department, the medical emergency and resuscitation service, and the forensic service. A bivariate analysis was performed to assess relevant clinical data that were entered into a logistic regression model to assess factors associated with death.

Results A total of 871 files were analyzed concerning 340 patients included after cross-checking. Victims were mainly males (90%) and young (30 ± 11 years old). The injury occurred mainly at night (60%), in a context of assaults (83%) and with long-barreled guns (82%). Among the 290 patients managed at the CGH, 60% were hospitalized including 12% that were in the intensive care unit, 41% that required surgical treatment, and 7% that died in hospital. The overall average length of stay was 10 ± 18 days. Overall mortality ($n = 71$, 21%) is statistically associated with male gender ($p = 0.007$) and suicide context ($p < 0.001$). In multivariate analysis, the sites of wounds (head and neck, thorax; $p < 0.001$) as well as induced organ injuries (neurological, respiratory, and vascular; $p < 0.005$) were independent factors associated to mortality.

Conclusions This work underlines the high incidence of ballistic trauma in FG. This mainly involves a young and male population linked to the use of long arms and assaults. Despite the geographical difficulties of the territory and the technical platform deficits (no neurosurgery, no cardiothoracic surgery, no interventional radiology), the mortality is comparable to other studies, but remains more than twice as high as in mainland France. Finally, despite a change in legislation restricting access to firearms, our results show that gunshot firearm injuries remain a major public health concern requiring greater political actions.

Keywords Ballistic trauma · Gunshot wounds · French Guiana · Epidemiology · Firearm injuries

Introduction

Firearm injuries are a major public health concern: 251,000 associated deaths worldwide in 2016 (3.4 deaths/100,000 persons per year) [1]. Currently, up to 875 million weapons are in circulation in the world, mostly in civilian hands (75%) [2]. Ballistic traumas cause acute injuries and chronic sequelae responsible for many disabilities [3]. They mainly

concern a young population and are significantly care-consuming [1]. Some studies have identified low socio-economic status and ownership of firearms as the main risk factors for firearm-related deaths [4]. In France, firearm-related deaths represent 5.5% of traumatic deaths [5].

French Guiana is a French overseas territory located in South America, bordering Suriname and Brazil. In 2017, there were 268,700 inhabitants with a high-density population on the coastline and nearly 30% living in Cayenne, the capital [6]. The healthcare network presents three level

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Extended author information available on the last page of the article

3 trauma centers located in the three main coastal towns (Cayenne, Kourou, and Saint-Laurent-du-Maroni) and 17 prevention and care centers located in remote areas [7, 8]. The main hospital is located in Cayenne where the intensive care unit, the major surgery specialties, and the emergency medical service can be found. But there was no neurosurgery, no cardiothoracic surgery, and no interventional radiology during the study period [9]. The nearest French level 1 trauma center is in the French West Indies, at 1500 km from Cayenne. These different parameters translate the difficulties in the management of severe injured victims.

French Guiana is the French territory with the highest rates of crime and violence [10]. Given its geography, French Guiana is a hotspot for illegal practices such as drug trafficking [11] and gold panning [12], generating a climate of violence. In 2018, there were an estimated 2.7 victims of gun violence assaults per 1000 inhabitants in French Guiana compared to 0.2 per 1000 in mainland France [13]. The homicide rate (1.3‰ inhabitants) is ten times higher than the national average [14]. In addition, Guianese population presents a high level of precariousness and strong social inequalities [15]. It is noteworthy that the authorization of weapon possession in French Guiana is different from the national legislation. Indeed, the weapons' sale was free (without permit) until 2017 [16] and remains nowadays more flexible than in mainland France. There are an estimated 55,000 weapons circulating in French Guiana (one weapon per six inhabitants) [2]. To date, there is no study evaluating the epidemiology and the management of ballistic trauma in French Guiana. Precise knowledge of the region's problem could permit to develop policy decisions and public prevention messages [17] and improving skills, care, and technical management resources [18], but also the creation of care structures for victims.

We therefore conducted a retrospective study at the Cayenne General Hospital (CGH) including all firearm injury victims. The primary objective was to describe the epidemiological profile and the initial management of victims. The second objective was to assess the outcome and the factors associated with death.

Material and methods

Study design and population

This is a retrospective, descriptive study conducted over a 4-year period (January 1st, 2016, to December 31st, 2019). This study was conducted before the SARS-COV period to avoid bias on epidemiologic data during the epidemic. We included all firearm wound victims managed by the mobile emergency medical service, the emergency department (ED), or the forensic unit (FU) of the Cayenne General Hospital. The non-inclusion criteria were stab wounds, nonballistic firearm wounds, weapon wound older than 7 days, and decline to participate.
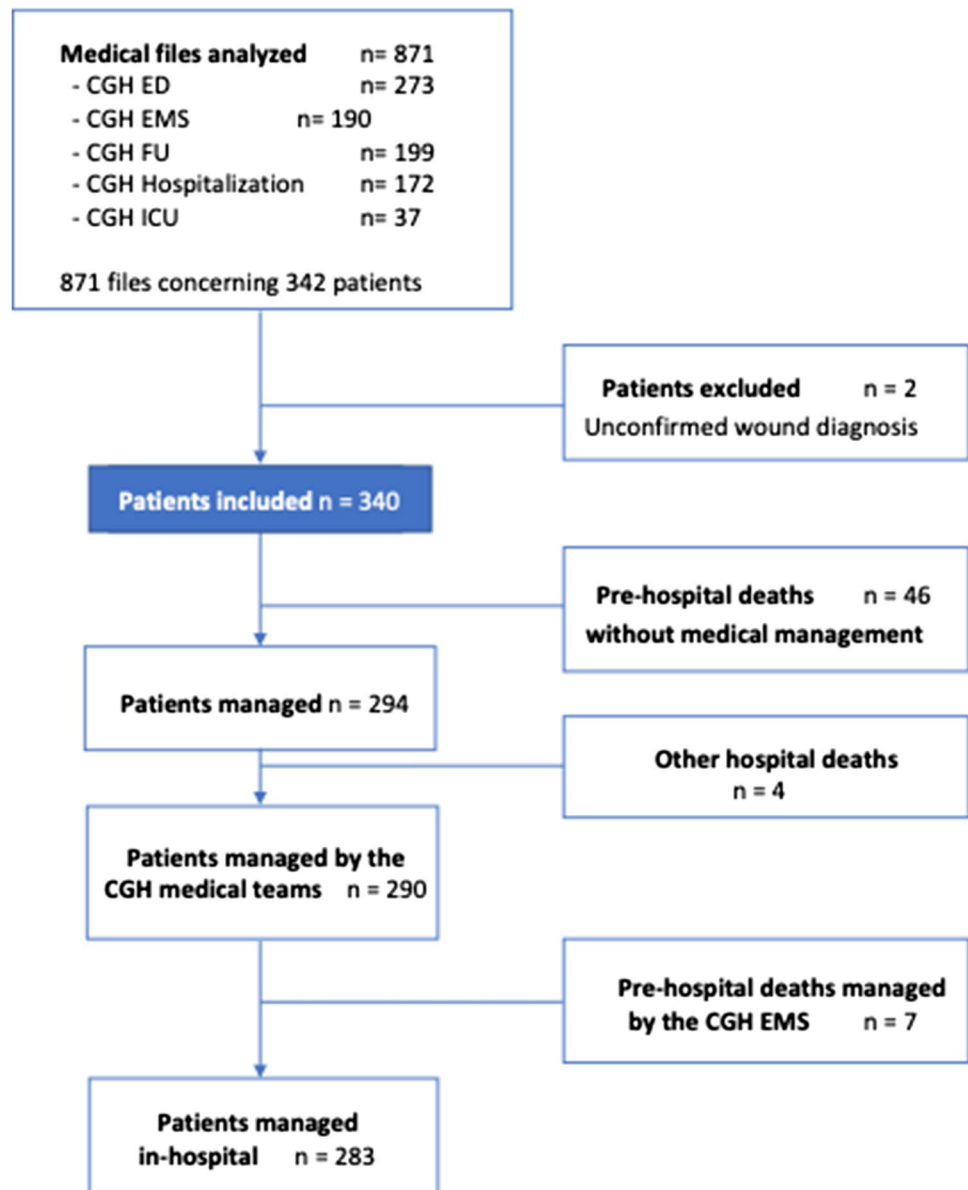
Data collection

Data were collected from the CGH computerized ED software, DMU Net® (Atos, Bezons, France), for all patients admitted with diagnoses related to a ballistic wound on International Statistical Classification of Diseases (ICD-10): W32-34, X72-74, X93-95, Y22-24. These data were crossed with the FU cases extracted from the victimology records and deceased victims' body examinations. Hospitalization records, imagery, and biology were verified. We collected the victims' demographic variables, the circumstances of the event, the parameters recorded during the pre-hospital period, the duration of hospitalization, and the status when victims leave the hospital (alive or dead). The criteria of severity were used as defined in the national guidelines for treatment of hemorrhagic shock: death, cardiopulmonary arrest, shock, shock index > 1, use of catecholamines, and the need for fluid infusion (> 1000 mL of intravascular solution) or mechanical ventilation during initial care. Data collection was completely managed by medical personnel, supervised by medical investigator trained in research and statistical analysis, which minimized missing data due to the retrospective protocol.

Statistical analysis

We created a data file with anonymized patient's information and performed descriptive analysis using Excel® (Microsoft Corp., Redmond, WA, USA) and IBM® SPSS® Statistics for Windows, version 24 (IBM Corp., Armonk, NY, USA). Continuous variables are expressed as mean ± standard deviation and compared using the Student t test. A Mann–Whitney U test was performed in case the population size was insufficient. The retrospective aspect of our study did not allow us to collect a certain amount of data. Some poorly completed or insufficiently accurate records may compromise the reliability of certain results. As our main objective was epidemiological, we decided to exclude missing data from the analyses. Categorical variables are expressed as numbers (percentages and 95% confidence intervals) and compared by the χ^2 test. A Fisher exact test was used for small samples. Time was expressed as hours and minutes. Non-redundant variables selected by bivariate analysis ($p \leq 0.05$) and considered clinically relevant were entered into the logistic regression model. Results are expressed as odds ratios (OR) with 95% confidence intervals (CI). All statistical tests were two-tailed, and $p \leq 0.05$ was considered significant.

Fig. 1 Study flow chart. CGH
Cayenne General Hospital, ED
emergency department, EMS
emergency medical service,
FU forensic unit, ICU intensive
care unit

Medical files analyzed   n= 871
- CGH ED   n= 273
- CGH EMS   n= 190
- CGH FU   n= 199
- CGH Hospitalization   n= 172
- CGH ICU   n= 37

871 files concerning 342 patients

Patients excluded   n = 2
Unconfirmed wound diagnosis

Patients included n = 340

Pre-hospital deaths   n = 46
without medical management

Patients managed n = 294

Other hospital deaths
n = 4

**Patients managed by the
CGH medical teams**   n = 290

**Pre-hospital deaths managed
by the CGH EMS**   n = 7

**Patients managed
in-hospital**   n = 283

Ethical and regulatory approval

This retrospective research was conducted according to
the national reference methodology MR-004 (Research
Not Involving the Human Person) of the National Com-
mission on Information Technology and Liberties (CNIL)
on July 16, 2018 (registered n°2224124v0), which frames
the processing of personal data for study, evaluation, or
research to which the Cayenne General Hospital has com-
mitted to comply according to the standards in force in
France. The data were pseudonymized and processed by
healthcare staff in the emergency department (principal
investigator or any person under his responsibility). In
addition, participants were collectively informed by post-
ers in the emergency department, in the welcome booklet,
and on the hospital website (general information on clinical
research). Any objections by patients to participating in the
study were considered and patients were then excluded.
A collective information was made and this research was
registered in the hospital internal treatment database and
also on the national Health Data Hub under the number
F20210505152609.

Results

Description of the general population

During the study period, we included 340 firearm wound
victims. The flow chart of the study is reported in Fig. 1.

Table 1 Demographic characteristics and incident circumstances

Variables	Victims ($n=340$) (mean or percentage)	CI 95% or SD
Demographic characteristics		
Age *(years) (n=334)*	30	± 11
Sex *(male) (n=340)*	306 (90%)	86–93%
< 18 years old	32 (10%)	7–13%
Incident circumstances		
Day time ($n=221$)		
Night (8:00 PM–8:00 AM)	132 (60%)	53–66%
Context ($n=318$)		
Assault	265 (83%)	79–87%
Accident	34 (11%)	7–15%
Suicide	13 (4%)	2–7%
Police arrest	6 (2%)	0.8–4%
Type of weapon ($n=108$)		
Hand gun	19 (18%)	11–27%
Long-barreled gun	89 (82%)	74–89%
Type of projectile ($n=314$)		
Bullets	154 (49%)	44–54%
Rifle leads	160 (51%)	45–56%
Shooting distance ($n=116$)		
Far-range shooting	36 (31%)	23–40%
Close-range shooting	65 (56%)	47–65%
In-contact shooting	15 (13%)	8–20%

CI confidence interval, *SD* standard deviation

Demographic characteristics and circumstances of events are described in Table 1. Our data revealed a sex ratio of M/F 9:1 with an age of 30 ± 11 years. The events involved long-barreled guns in 82% and an assault context in 83% of cases.

We counted 101 victims including 22 (22%) deaths in 2016, 53 victims in 2017 including 14 (26%) deaths, 83 in 2018 including 17 (20%) deaths, and 102 in 2019 including 18 (18%) deaths. The geographic distribution of victims is presented in Fig. 2. The Cayenne agglomeration accounted for 233 (72%) of the trauma victims, including 170 (50%) cases in Cayenne.

Management of victims

Over the 340 studied patients, 46 died without medical intervention, 4 died in other hospitals, and 290 victims were managed at the CGH. The overall mean length of hospital stay was 10 ± 18 days. A description of the management modalities is presented in Table 2. Over the 253 patients who received imaging, 15 (6%) had FAST ultrasounds and 146 (58%) had CT scans, and in 155 (61%) X-rays were performed. Regarding resuscitation maneuvers, 40 (14%) patients required abundant fluid infusion (≥ 1000 mL), 28 (10%) required blood transfusion, 26 (9%) required catecholamines, and 26 (9%) required mechanical ventilation. Finally, 117 (41%) required

emergent surgery and 36 (12%) an admission in the intensive care unit. The average time from hospital admission to surgery was 9h16 $\pm$ 11h57. Return to home after emergency care was recorded in 117 patients (40%). The in-hospital mean length of stay was 17 ± 21 days, and the intensive care unit mean length of stay was 20 ± 32 days. There were 14 (5%) in-hospital deaths and 7 (2%) pre-hospital deaths.

An analysis to identify the associations between the injured anatomical sites is detailed in Fig. 3. Bone injuries ($n=152$) were statistically associated with central neurological ($n=40$), vascular ($n=63$), and respiratory ($n=68$) injuries. There was also a strong association between vascular injuries and respiratory and digestive injuries ($n=53$).

Mortality and outcome

A comparison of survived versus died victims is presented in Table 3. Overall, mortality was estimated at 6.3/100,000 population per year. We counted 21 (7%) deaths among patients managed at the CGH. We did not find significant differences according to the type of weapon, the projectile used, or the presumed shooting distance. Additionally, the location of the event did not have an impact on mortality (coastal municipalities versus remote municipalities, $p=0.30$). On the other hand, male gender ($p=0.026$), daytime occurrence ($p=0.008$), and suicides circumstances ($p=0.002$) were significantly associated with death.

We also assessed the association between penetrating wound sites and mortality (Fig. 4): head and neck ($p<0.001$) and thoracic involvement ($p<0.001$) were associated with mortality. The presence of retained bullet fragments was also associated with death (84% *vs.* 65%, $p=0.003$).

Multivariate analyses assessing associated factors to death are shown in Fig. 5. Five variables selected by bivariate analysis and considered clinically relevant were used into the logistic regression model (number of wounds injury < 3, central nervous system injury, vascular injury, digestive injury, respiratory injury). Of these, three were significantly associated with an increased risk of death. Victims had an estimated relative risk of death 86 times and 36 times higher respectively when they had a central neurological injury ($p<0.001$) or a vascular injury ($p<0.001$). Respiratory injury showed a 13-fold higher odds ratio of death ($p=0.003$).

Discussion

This study describes the epidemiology of firearm injuries managed at the Cayenne General Hospital. This is the first study on the topic in French Guiana and one of the largest cohorts of civilian ballistic trauma victims in France. The population was predominantly young, male, and victim of assaults
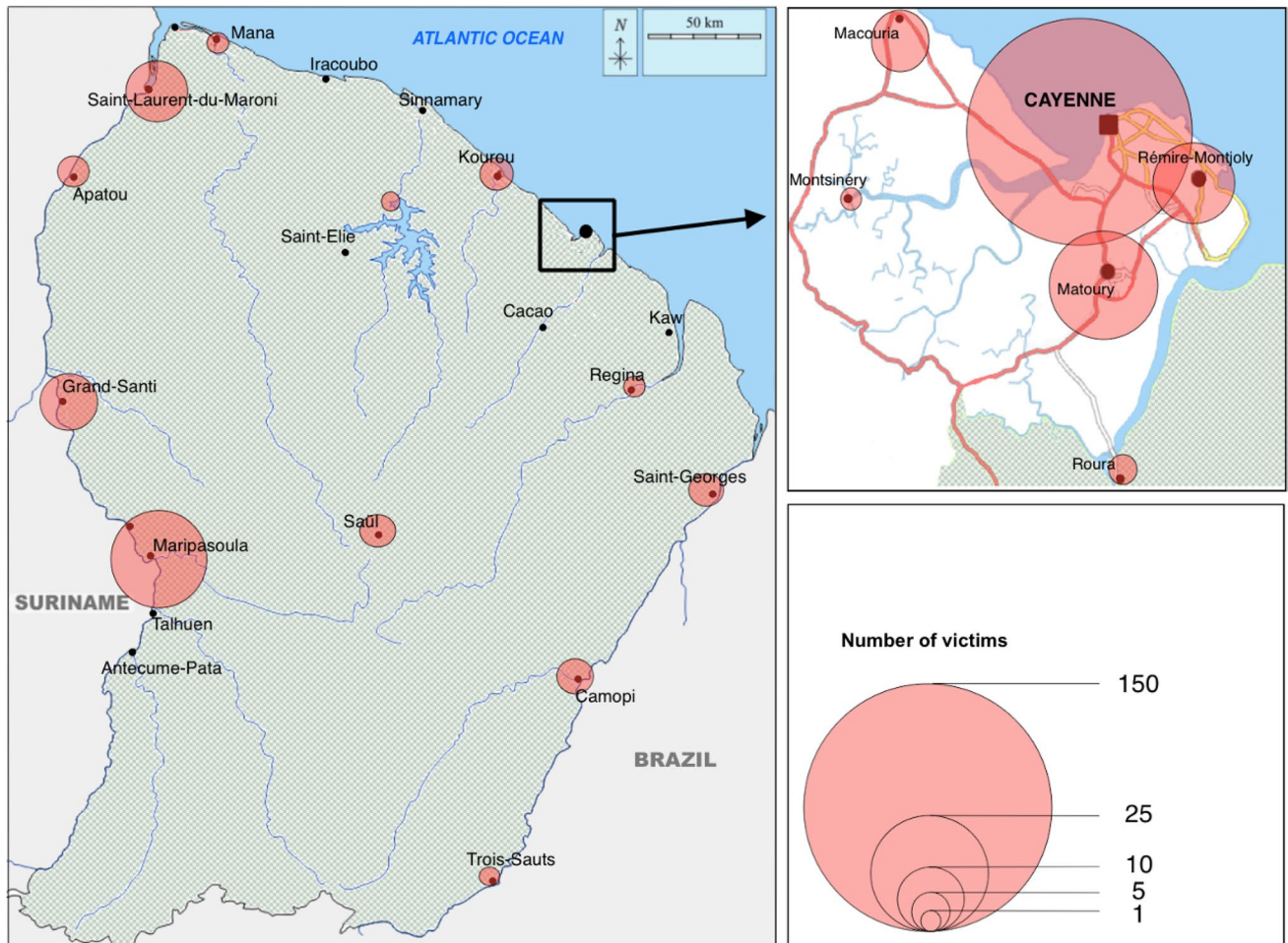
Fig. 2 Geographic distribution of victims

with a long-barreled gun. The population at risk found in our work but also circumstances are close to those found in the worldwide epidemiology of ballistic trauma [1]. This is all the more interesting given that 51% of the world's firearm civilian deaths occur in six American countries, including some of French Guiana neighbors.

One of the points of this study was to describe the management of these patients. First of all, pre-hospital care by emergency medical service appears to be lower than in the USA (47% *vs.* 68%) [19]. Contrary to the Anglo-Saxon paramedics organization, in France, out-of-hospital emergency teams are organized on duty 24/7 and include doctors. For less severe injuries, teams of first rescuers not considered emergency medical service but with basic life support knowledge are mobilized. Regarding surgery, the proportion of surgical managements in our series is twice than in a US cohort study in 2021 [20]. This is probably due to our method including all patients needing emergency surgery compared

to other studies excluding patients directly transferred to the emergency surgery room. We also note that the American studies mention a more frequent hospitalization rate (65% *vs.* 60%) as well as hospitalization in the intensive care unit (31% vs. 12%) [20]. In view of these results, it might seem that our population suffered less severe ballistic trauma than those reported in the literature. However, the mean length of stay in the intensive care unit is four times shorter in the USA (5 days *vs.* 20 days) than in our study.

Regarding mortality, the intra-hospital mortality rate was 4.8%, lower than in several American countries [1, 20]. The overall mortality (6.3/100,000 inhabitants/year) is significantly lower than results reported in the neighboring countries: 19.4/100,000 in Brazil and 10.6/100,000 in the USA but two to three times higher than the French national rate (2.7/100,000 inhabitants/year) [1]. These rates follow the overall crime rates and gun laws in the different countries. As found in previous works, our

**Table 2** Description of patient's management and post ED orientation

Variables	Victims managed in the CGH (n=290) (mean or percentage)	CI 95% or SD
Pre-hospital data		
Call to EMS call center (n=287)	175 (61%)	55–66%
EMS management (n=286)	134 (47%)	40–52%
Incident—hospital admission delay (n=195)	2h39	±4h14
Complementary exams		
Blood test (n=288)	199 (69%)	63–74%
Imaging	253 (87%)	83–91%
Initial management		
Resuscitation maneuvers (n=287)	50 (17%)	13–22%
Antibiotic therapy (n=286)	223 (78%)	73–83%
Blood transfusion (n=285)	28 (10%)	7–14%
Emergent surgery (n=288)	117 (41%)	35–46%
Post ED orientation		
Hospitalization	173 (60%)	54–65%
Intensive care unit admission	36 (12%)	9–17%
Death	21 (7%)	5–11%

CGH Cayenne General Hospital, *CI* confidence interval, *SD* standard deviation, *EMS* emergency medical service, *ED* emergency department

study identifies factors associated with an increased risk of death such as male gender or suicide context [1, 21]. In our results, deaths are associated with assaults in 80% and suicides in 11% of cases. Comparatively, in mainland France, suicide is the main cause of firearm-related deaths (79%) and concerns an older population [5]. In the

USA, suicide accounts for 60% of firearm deaths [22]. The low suicide rate in our population could explain part of the difference about global mortality.

As described in the work of Maiden in 2009, who studied ballistics in firearm injuries, the study of wound sites and induced injuries finds a major impact on lethality
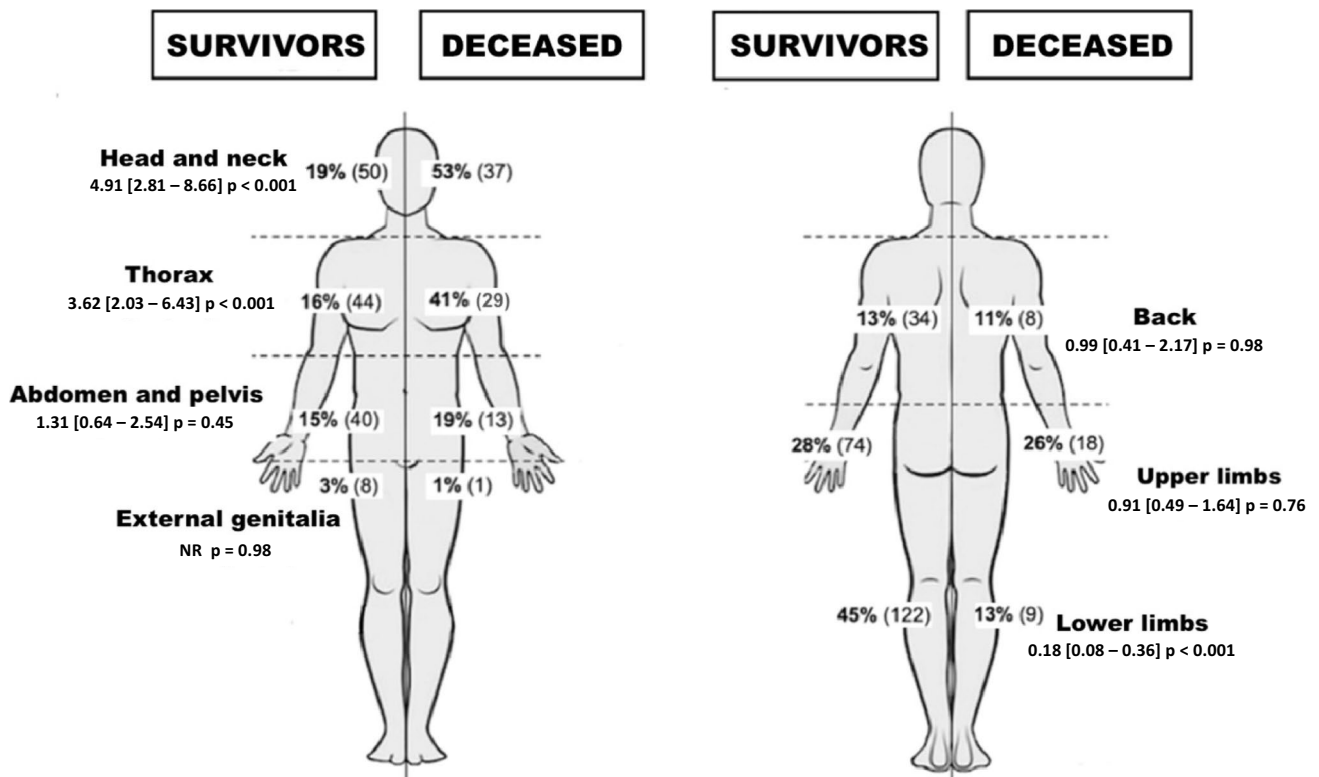

Fig. 3 Associations between the injured anatomical sites
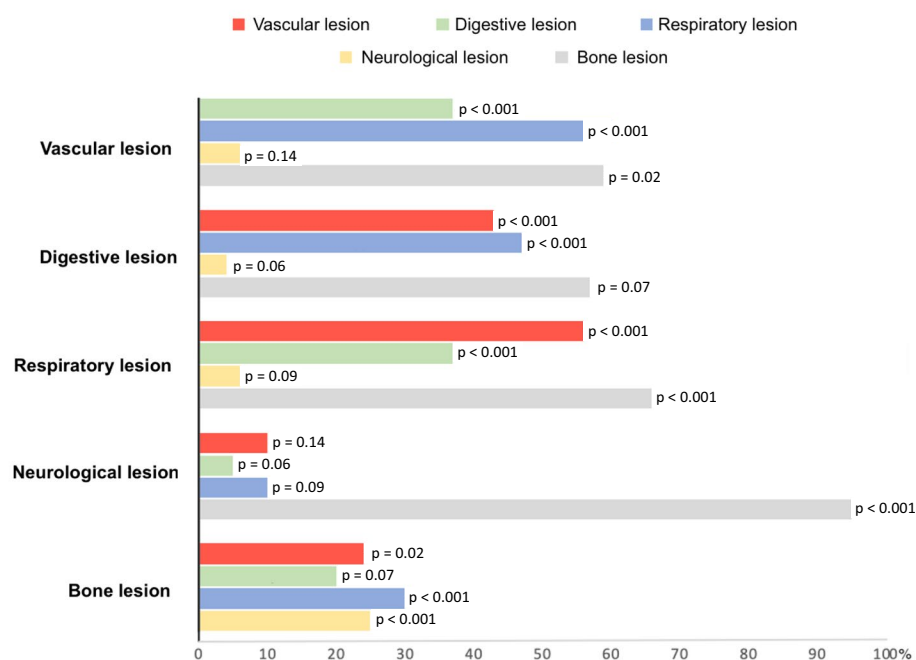
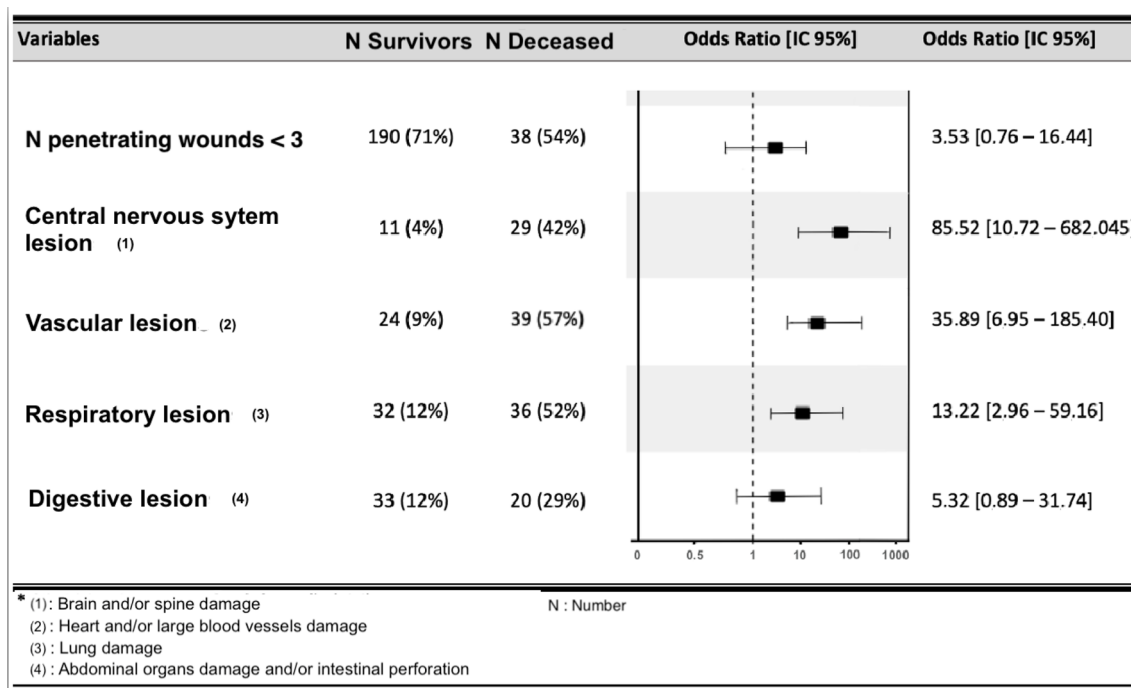**Table 3** Comparison of patient's characteristics according to outcome

Variables	Surviving patients (n=269)	Deceased patients (n=71)	Odds ratio [IC 95%]	p value
Demographic characteristics				
Sex *(male)*	236 (88%)	70 (99%)	9.8 [2.05–175.6]	**0.026**
Age *(years)* (n=334)	29±11	33±14	1.02 [1.00–1.05]	0.027
<18 years old	26 (10%)	6 (9%)	0.93 [0.33–2.23]	0.88
Incident circumstances				
Day time (n=221)				
Night (8:00 PM–8:00 AM)	118 (63%)	14 (40%)	0.38 [0.19–0.77]	**0.008**
Context (n=318)				
Assault	209 (84%)	56 (80%)	1.5 [0.62–4.73]	0.38
Accident	29 (12%)	5 (7%)	0.64 [0.21–1.61]	0.38
Suicide	5 (2%)	8 (11%)	9.3 [2.25–44.1]	**0.002**
Police arrest	5 (2%)	1 (1%)	1.16 [0.05–9.54]	0.79
Arm				
Long-barreled gun	56 (78%)	33 (92%)	3.14 [0.96–14.2]	0.074
Bullet (vs. pellets)	123 (50%)	31 (45%)	0.81 [0.47–1.38]	0.439
Management				
Incident—hospital admission delay	2h41±4h19 (n=184)	2h05±2h42 (n=12)	0 .99 [0.99–1.00]	0.635

[22]. In our series, head and/or neck and thorax injuries are associated with increased mortality. As found in a previous study, central neurological, respiratory, and vascular injuries are also associated with an increased risk of death [22, 23]. This finding is particularly interesting in terms of assessing the Cayenne Hospital's technical facilities. Although these lesions can be very damaging and even life-threatening, requiring emergency surgery,

Fig. 4 Sites of injuries compared to the survival status of patients (n=340)

Variables	N Survivors	N Deceased	Odds Ratio [IC 95%]	Odds Ratio [IC 95%]
N penetrating wounds < 3	190 (71%)	38 (54%)		3.53 [0.76 – 16.44]
Central nervous sytem lesion (1)	11 (4%)	29 (42%)		85.52 [10.72 – 682.045]
Vascular lesion _ (2)	24 (9%)	39 (57%)		35.89 [6.95 – 185.40]
Respiratory lesion (3)	32 (12%)	36 (52%)		13.22 [2.96 – 59.16]
Digestive lesion (4)	33 (12%)	20 (29%)		5.32 [0.89 – 31.74]

* (1): Brain and/or spine damage   N : Number
(2): Heart and/or large blood vessels damage
(3): Lung damage
(4): Abdominal organs damage and/or intestinal perforation

Fig. 5 Multivariate analysis assessing the independent factors associated to mortality

stomatology, neurosurgery, and cardiothoracic surgery is under-represented or even absent in French Guiana [24, 25]. Induced mortality could be the direct cause of the absence of these specialties in our territory. In support of this hypothesis, abdominal-pelvic lesions, although frequently reported as fatal in the literature, are not so in our work, our hospital being adequately staffed with digestive surgeons [26].

Several areas for improvement emerge from this work in line to implement research on this topic insufficiently studied [27]. The most important issues accessible to primary prevention are violence and crime control, and gun laws: the population at risk being mainly young male victims of assault. According to Santaella-Tenorio's study in 2016, gun ownership legislation as well as the number of weapons circulating is correlated with the number of related deaths [28]. Since 2017, the French Guiana Police Commissioner started to regulate the use and possession of firearms [16]. Despite its implementation in 2017, our work did not show a decrease in the number of firearm trauma victims during the study period. The high incidence of deaths from 2017 to 2019 follows the trend of violence and delinquency markers over the same period [12]. However, the continuous monitoring is necessary to evaluate the results of this new regulation in the medium and long term. This observation, as well as multiple proposals to fight violence, gold panning, and drug trafficking, is reported in the French Senate report in February 2020 [12].

CGH does not fill the characteristics of a "trauma center" due to a lack of some technical skills and facilities. There is also a large deficit in terms of intensive care capacity [29]. This aspect is responsible for long, costly, and often risky medical evacuations to specialized hospital centers in the French Caribbean islands or in mainland France [29]. The availability of interventional radiology techniques since 2020, the implementation of an observational database (TraumaBase®) in 2021, and the training of remote health center teams (university degrees: "severe trauma and life-threatening emergencies" and "initiation to emergency medicine") since 2022 are the first responses for improving management of these patients [30–33].

Our study presents several limitations. First, this is a monocentric study. However, CGH is the referral and the main hospital in French Guiana with the majority of specialties, intensive care unit, and mobile emergency medical service. Second, this is a retrospective study with numerous missing data which leads to the classic biases of this methodology. The implementation of the TraumaBase® registry will allow a complete prospective data collection and a correct outcome evaluation of these traumas [31, 34]. Nevertheless, this study reports interesting results to understand the burden of firearm injuries in French Guiana. This work is a first step to adapt legislative texts according to the department context as it is discussed in the USA but also to improve medical care according to the national and international guidelines [35, 36].

Conclusion

As reported in several American countries, this study highlights the significant incidence of ballistic trauma in French Guiana and the overexposure of young patients, victims of assaults with long-barreled guns. In spite of the geographical territory difficulties and the deficits in some technical procedures, the mortality remains low.

Author contribution Alexis Fremery: conception, design, analysis, writing.

Elliott Beguinot: collection of data, analysis, writing.

Angélique Franchi: reviewing.

Mathilde Douchet: collection of data.

Victor Tertre: collection of data.

Karim Hamiche: reviewing.

Antoine Adenis: reviewing.

Jean Marc Pujo: reviewing.

Hatem Kallel: conception, analysis, reviewing.

Data availability The authors confirm that the data supporting the findings of this study are available on demand.

Declarations

Conflict of interest The authors declare no competing interests.

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