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Neurological outcome of cardiac arrest patients in mountain areas: An analysis of the Northern French Alps Emergency Network

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ABSTRACT

Background: Mountainous areas pose a challenge for the out-of-hospital cardiac arrest (OHCA) chain of survival. Survival rates for OHCA in mountainous areas may differ depending on the location. Increased survival has been observed compared to standard location when OHCA occurred on ski slopes. Limited data is available about OHCA in other mountainous areas. The objective was to compare the survival rates with a good neurological outcome of OHCA occurring on ski slopes (On-S) and off the ski slopes (Off-S) compared to other locations (OL). **Methods:** Analysis of prospectively collected data from the cardiac arrest registry of the Northern French Alps Emergency Network (RENAU) from 2015 to 2021. The RENAU corresponding to an Emergency Medicine Network between all Emergency Medical Services and hospitals of 3 counties (Isère, Savoie, Haute-Savoie). The primary outcome was survival at 30 days with a Cerebral Performance Category scale (CPC) of 1 or 2 (1: Good Cerebral Performance, 2: Moderate Cerebral Disability).

Results: A total of 9589 OHCA were included: 213 in the On-S group, 141 in the Off-S group, and 9235 in the OL group. Cardiac etiology was more common in On-S conditions (On-S: 68.9% vs Off-S: 51.1% vs OL: 66.7%, $p < 0.001$), while Off-S cardiac arrests were more often due to traumatic circumstances (Off-S: 39.7% vs On-S: 21.7% vs OL: 7.7%, $p < 0.001$). Automated external defibrillator (AED) use before rescuers' arrival was lower in the Off-S group than in the other two groups (On-S: 15.2% vs OL: 4.5% vs Off-S: 3.7%; $p < 0.002$). The first AED shock was longer in the Off-S group (median time in minutes: Off-S: 22.0 (9.5–35.5) vs On-S: 10.0 (3.0–19.5) vs OL: 16.0 (11.0–27.0), $p = 0.03$). In multivariate analysis, on-slope OHCA remained a positive factor for 30-day survival with a CPC score of 1 or 2 with a 1.96 adjusted odds ratio (95% confidence interval (CI), 1.02–3.75, $p = 0.04$), whereas off-slope OHCA had an 0.88 adjusted odds ratio (95% CI, 0.28–2.72, $p = 0.82$).

Conclusions: OHCA in ski-slopes conditions were associated with an improvement in neurological outcomes at 30 days, whereas off-slopes OHCA were not. Ski-slopes rescue patrols are efficient in improving outcomes.

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1. Introduction

Out-of-hospital cardiac arrest (OHCA) has an annual incidence in Europe ranging from 67 to 170 cases per 100,000 inhabitants, with an average survival rate of 8% [1]. This represents a significant public health

concern. The initial phase of the survival chain is crucial, beginning with the recognition of cardiac arrest by a witness, followed by the initiation of basic life support (BLS) involving thoracic compressions and early use of an automated external defibrillator (AED), and subsequent advanced life support provided by emergency medical services (EMS) [2]. Mountain sports are enjoyed by millions of people worldwide. In France, during a single winter season, there are 53.9 million skier days and >49,000 rescue interventions [3]. Furthermore, summer mountain activities are increasing, along with related mortality [4]. Although the

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incidence of cardiac arrest remains low on ski slopes [5], it is important to analyse the epidemiology of OHCA in these specific conditions. The mountainous environment presents unique challenges and has its own specialized rescue organization. On ski slopes, there is a high number of potential witnesses and dedicated rescue teams that can promptly administer BLS. In contrast, accessibility is significantly limited in other mountainous areas without patrol teams. While helicopter transport facilitates rapid and adapted responses, factors such as altitude, weather conditions, and avalanche risk can represent a challenge for rescuers and Emergency Medical Services (EMS). A previous study demonstrated that the 30-day survival rate of OHCA on ski slopes is higher than that of cardiac arrests occurring in other out-of-hospital settings [6]. This study showed that patients experiencing cardiac arrest on ski slopes were younger, with a more frequent initial shockable rhythm, and CPR was more frequently initiated by a witness. However, to date, no study has specifically addressed cardiac arrests occurring in mountainous areas, off ski zones, and their impact on neurological outcomes. Therefore, understanding the epidemiology of cardiac arrests in these conditions is crucial to enable EMS operating in these areas to adapt their practices. The aim of this study was to assess and compare the neurological outcomes of out-of-hospital cardiac arrest (OHCA) patients on ski slopes and in other mountainous areas with those in other locations.

2. Methods

2.1. Study design

We carried out an observational prospective cohort study with an analysis of all patients presenting an OHCA in the Northern French Alps between January 1st, 2015, and December 31st, 2021. We excluded OHCA patients without attempted resuscitation and OHCA patients with an unknown location.

2.2. The Northern French Alps Cardiac Arrest Registry

This study is based on patient data prospectively collected from 2015 to 2021 by the Northern French Alps Cardiac Arrest Registry, as previously described [6,7]. All patients for whom EMS was dispatched to start cardiopulmonary resuscitation following OHCA were included in the registry. The Northern French Alps Emergency Network (RENAU) comprises all hospitals and EMS systems in the three counties (Isère, Savoie and Haute-Savoie), including 13 Mobile Emergency and Resuscitation Services, primary care physicians in ski resorts with training and equipment to handle medical emergencies, and other rescue services (fire department, ski-patrols, etc.). The area covers 18,000 km² with a population of 2 million inhabitants, including >100 ski resorts, and up to nine rescue helicopters intervene on the network's ski slopes (Appendix 1). The RENAU network also includes some border county areas (Hautes-Alpes, Drôme, Ain). Since January 1st, 2015, each case of OHCA has been recorded in electronic form completed by the emergency medicine physician in charge of the patient and the dispatch center. The form includes relevant variables such as age, place of OHCA, presence of a witness, CPR, initial cardiac rhythm recorded, presumed etiology, defibrillation, and intervention times. The patient's status (alive/dead and date of death, cerebral performance category [CPC], date of discharge) was obtained at 30 days from the receiving unit, and research associates performed phone interviews for the 30-day status if the hospital discharge was obtained. Since 2015, two new categories have been added to the registry to differentiate locations: "on ski slopes" and "off ski slopes." In France, ski areas are clearly defined by the urbanism code and the area is well delimited. Thus, an "on-slopes" OHCA was defined as a cardiac arrest occurring on a ski slope within a ski resort, as delineated by the French urbanism code. Ski slopes fall under the responsibility of the ski resort, which provides dedicated rescuers and rescue responses. The activities conducted on ski slopes mainly include skiing, cross-country skiing or snowboarding during

winter, and mountain biking during summer. "Off-slopes" OHCA was defined as a cardiac arrest that occurs outside a ski slope or ski resort, meaning an off-slopes OHCA can happen anywhere in a mountain area. The range of sports outside ski slopes is broad, including backcountry skiing, alpinism, hiking, mountain biking, paragliding, among others. The physician responsible for the patient recorded the case in the RENAU OHCA registry and determined the location. *The distinction between on-slope and off-slope is easy since slopes in ski resort are groomed.* These data were then verified by a research assistant upon database implementation. "Other locations" OHCA was defined as a cardiac arrest occurring in areas other than on-slopes or off-slopes. *This category included usual locations defined in the Utstein template: homes, public places, public roads, medical or social establishments, workplaces, and others.*

Our primary outcome was to compare survival at 30 days with a Cerebral Performance Category scale 1 or 2 for on-slopes (On-S) and off-slopes (Off-S) cardiac arrest compared to other locations (OL). Our secondary outcome was to compare other survival rates (ROSC, survival at hospital discharge and survival at 30 days) for On-S and Off-S cardiac arrest compared to OL.

The study complied with the Declaration of Helsinki and was approved by the ethics committee of the University Hospital of Clermont-Ferrand, Clermont-Ferrand, France (IRB no. 5891).

2.3. Statistical analysis

On-slopes and on-mountains OHCA were compared to OHCA occurring in other locations (at home, public places, public highway, medical establishment, at work, other). The qualitative variables are expressed as numbers and percentages and were compared with a chi² test or Fisher's exact test when appropriate. For continuous variables, we calculated the mean \pm standard deviation (SD) and minimum and maximum for normally distributed data or median and interquartile range (IQR) in the case of skewed distribution. They were compared using an ANOVA test for the comparison of the three groups and with an independent Student's *t*-test for two group comparisons. Times to intervention were calculated from the first emergency call. To quantify the univariable associations between neurological outcomes and the locations of OHCA, crude (unadjusted) odds ratios (ORs) with 95% confidence intervals were calculated with ANOVA or chi-squared tests. A multivariate binomial logistic regression analysis was performed on the explanatory variables of survival (age, sex, witnessed cardiac arrest, time from call to first shock, the characteristics of CA -initial rhythm and presumed etiology- and the season) to determine the survival OR of an On-S OHCA and Off-S OHCA. The missing data were not replaced. All tests were bilateral with an alpha risk of 0.05. Analyses were performed using Jamovi software (Version 2.3.21.0).

3. Results

3.1. Study sample

Between 2015 and 2021, 10,317 OHCA with a resuscitation attempt occurred. We excluded 728 patients due to an unknown location in the registry. 9589 OHCA were included in the study; we identified 213 OHCA on ski-slopes (On-S), 141 off the ski-slopes (Off-S), and 9235 on other locations (OL) (Fig. 1).

In mountain conditions (i.e., On-S and Off-S), OHCA patients were more often men (On-S: 89.7% vs Off-S: 90.1% vs OL: 67.6%, $p < 0.001$) and younger (On-S: 57.1 ± 16.2 vs Off-S: 54.4 ± 17.9 vs OL: 67.0 ± 19.7 ; $p = 0.007$). All the patient's characteristics are detailed in Table 1.

Compared to on-mountain cardiac arrest, On-S OHCA occurred more often during winter (On-S: 44.6% vs Off-S: 27.7%, $p < 0.001$), while Off-S OHCA occurred more often during the summer (On-S: 18.3% vs Off-S: 32.6%, $p < 0.001$). Cardiac etiology was more often in

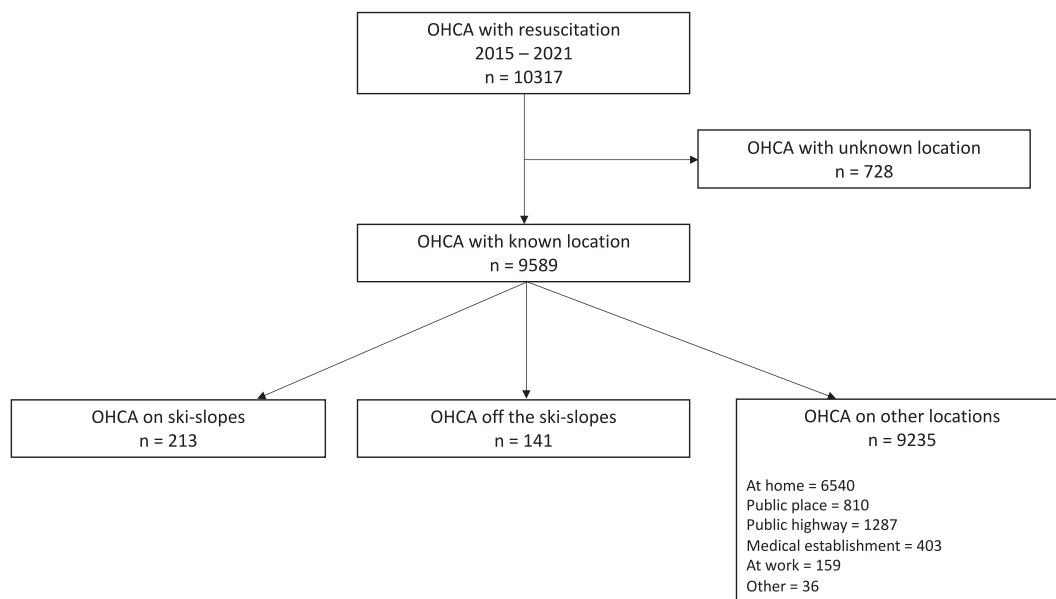


Fig. 1. Study Flow Chart.
OHCA: Out-of-hospital cardiac arrest.

On-S conditions (On-S: 68.9% vs Off—S: 51.1%, $p < 0.001$), while Off-S CAs were more often due to traumatic circumstances (Off—S: 39.7% vs On-S: 21.7%, $p < 0.001$) and hypothermia (Off—S: 5.0% vs On-S: 1.4%, $p < 0.001$). However, bystander CPR was similarly frequent between

On-S and Off-S cardiac arrest (Off—S: 63.6% vs On-S: 62.6%, $p = 0.87$) and more frequent in mountain conditions compared to other locations (OL: 49.5%, $p < 0.001$ between the 3 groups). AED use before rescuer arrival was lower in mountainous conditions (Off—S: 4.5% vs On-S: 15.2%;

Table 1
Population characteristics.

	On-Slopes (n = 213)	On-Mountains (n = 141)	Other locations (n = 9235)	p
Male gender – n (%)	191 (89.7)	127 (90.1)	6240 (67.6)	<0.001
Age, year – mean (SD)	57.1 (16.2)	54.4 (17.9)	67.0 (19.7)	0.007
Season – n (%)				
Winter	95 (44.6)	39 (27.7)	2569 (27.8)	
Spring	62 (29.1)	31 (22.0)	2281 (24.7)	
Summer	39 (18.3)	46 (32.6)	2222 (24.1)	<0.001
Autumn	17 (8.0)	25 (17.7)	2163 (23.4)	
Presumed Etiology – n (%)				
Cardiac	146 (68.9)	72 (51.1)	6143 (66.7)	
Traumatic	46 (21.7)	56 (39.7)	711 (7.7)	<0.001
Respiratory	8 (3.8)	2 (1.4)	1085 (11.8)	
Other/Unknown	12 (5.7)	11 (7.8)	1273 (13.8)	
Hypothermia	3 (1.4)	7 (5.0)	8 (0.1)	< 0.001
Witnessed arrest – n (%)				
Non-witnessed	34 (16.4)	21 (15.6)	2870 (31.6)	
Ordinary people	122 (58.9)	96 (71.1)	4862 (53.5)	<0.001
Rescuers	51 (24.6)	18 (13.3)	1363 (15.0)	
Bystander CPR	103 (63.6)	77 (62.6)	3698 (49.5)	<0.001
AED use before rescuers arrival	30 (15.2)	6 (4.5)	316 (3.7)	<0.001
First documented rhythm – n (%)				
Ventricular Fibrillation / Ventricular Tachycardia	75 (41.2)	25 (21.2)	1550 (19.6)	
Asystole	102 (56.0)	92 (78.0)	5701 (72.0)	<0.001
Pulseless electrical activity	5 (2.7)	1 (0.8)	669 (8.4)	
ECLS at hospital	10 (4.7)	5 (3.5)	147 (1.6)	<0.001
Time from call to, min – median (IQR)				
First CPR	0.0 (0.0–25.0)	2.0 (0.0–15.0)	6.0 (0.0–13.0)	0.171
First shock	10.0 (3.0–19.5)	22.0 (9.5–35.5)	16.0 (11.0–27.0)	0.03
Rescuers arrival	10.0 (1.0–18.0)	20.0 (11.0–29.0)	12.0 (8.0–17.0)	<0.001
Medical Team arrival	24.5 (15.0–37.0)	31.0 (20.0–40.0)	23.0 (16.0–33.0)	0.006
Duration of CPR after medical team arrival	26.5 (15.0–40.0)	30.0 (20.0–40.0)	20.0 (9.0–30.0)	<0.001
ROSC	16.0 (8.0–16.0)	50.0 (33.0–62.0)	31.0 (21.0–43.0)	<0.001

Abbreviations: OHCA: out-of-hospital cardiac arrest; CPR: cardiopulmonary resuscitation; ROSC: return of spontaneous circulation; ECLS: extracorporeal life support. Chi-squared or Fisher's exact tests were performed for categorical variables, and one-way ANOVA was performed for continuous variables.

On-slopes: cardiac arrest on ski-slopes; On-mountains: cardiac arrest on mountainous area off ski slopes; Other locations: at home, public place, public highway, medical establishment, at work, other.

Table 2
Results of multivariate model for 30-day survival with CPC 1 or 2 comparing CPC 3–5 for on-slopes and on-mountains cardiac arrest.

	CPC 1–2 (n = 564)	CPC 3–5 (n = 9025)	Unadjusted OR (95% CI)	Adjusted OR (95% CI)
Age – mean, (SD)	57.4 (18.8)	67.2 (19.7)	0.98 (0.97–0.98)	0.97 (0.96–0.98)
Sex (male) – n (%)	441 (78.1)	6117 (67.7)	0.59 (0.48–0.72)	0.88 (0.61–1.26)
Bystander CPR – n (%)	295 (52.3)	3523 (39.0)	2.67 (2.15–3.33)	1.52 (1.12–2.08)
Initial Shockable Rhythm – n (%)	421 (74.6)	1543 (17.1)	16.48 (13.35–20.35)	11.14 (5.54–22.01)
Delay from call to first shock – median (IQR)	13.0 (9.0–24.5)	17.0 (12.0–27.0)	0.99 (0.99–1.01)	0.99 (0.99–1.00)
Presumed etiology of cardiac arrest				
Cardiac – n (%)	465 (82.4)	5895 (65.3)	Reference	Reference
Traumatic – n (%)	7 (1.2)	806 (8.9)	0.11 (0.05–0.23)	0.10 (0.01–0.73)
Respiratory – n (%)	39 (6.9)	1056 (11.7)	0.47 (0.34–0.65)	0.20 (0.05–0.82)
Others / Unknown – n (%)	51 (9.0)	1245 (13.8)	0.52 (0.39–0.70)	0.14 (0.04–0.48)
Season				
Winter – n (%)	147 (26.1)	2556 (28.3)	Reference	Reference
Spring – n (%)	153 (27.1)	2221 (24.6)	1.20 (0.95–1.51)	1.15 (0.79–1.68)
Summer – n (%)	138 (24.5)	2168 (24.0)	1.11 (0.88–1.42)	1.11 (0.78–1.62)
Autumn – n (%)	125 (22.2)	2080 (23.0)	1.04 (0.82–1.34)	1.31 (0.90–1.91)
Location of cardiac arrest				
Other locations – n (%)	531 (94.1)	8704 (96.4)	Reference	Reference
On slopes – n (%)	27 (4.8)	186 (2.1)	2.38 (1.57–3.60)	1.96 (1.02–3.75)
On mountains – n (%)	6 (1.1)	135 (1.5)	0.73 (0.32–1.68)	0.88 (0.28–2.72)

On-slopes: cardiac arrest on ski-slopes; On-mountains: cardiac arrest on mountainous area off ski slopes; Other locations: at home, public place, public highway, medical establishment, at work, other. Abbreviations: CI Confidence Interval, CPR Cardio-Pulmonary Resuscitation.

$p < 0.002$). Concerning time delays, the first AED shock was longer in the Off-S group than in the two others (median time in minutes: Off-S: 22.0 (9.5–35.5) vs On-S: 10.0 (3.0–19.5) vs OL: 16.0 (11.0–27.0), $p = 0.03$).

3.2. Survival outcomes

In the multivariate analysis, an on-slopes OHCA patient was more likely to survive with a CPC of 1 or 2 at 30 days, with an adjusted OR of 1.96 (95% CI: 1.02–3.75), while an off-slopes patient had an adjusted OR of 0.88 (0.28–2.72) compared to other locations (Table 2).

Compared to other locations, ROSC was more frequent in the on-slopes group, with an adjusted OR of 1.93 (1.11–3.37). Survival at hospital discharge was higher in the on-slopes group, with an adjusted OR of 2.99 (1.64–5.45) (Table 3). The off-slopes group had the lowest 30-day survival rate (for all CPC scores), with an adjusted OR of 0.95 (0.33–2.70).

4. Discussion

While it was already observed that survival outcomes were improved during on-ski-slopes OHCA [6], this is the first study to assess the neurological outcomes of these specific patients. On-slopes patients were younger and more often male with an increased proportion of initial shockable rhythm. Our main result for on-slopes cardiac arrest is the improvement of the neurological status at 30 days with a significant adjusted OR of 1.96. Moreover, we added new insights assessing cardiac arrest in other mountain areas outside the specific slopes area. For this

specific population, the outcomes were worse than those of the on-ski slope group but not different than those of cardiac arrest in standard locations. However, these difficulties should not limit rescue operations, and EMS organizations should work to optimize their training and resources.

For on-slopes conditions, the main determinants of the favorable outcomes observed are related to the rescue organization on ski slopes. Indeed, rescue team patrols are dedicated to these areas with a high level of training and early arrivals on scenes with AEDs. Moreover, ski-slopes are crowded locations with a high level of witnesses, which improves outcomes [18]. Finally, on-slopes cardiac arrests represent an example of the ideal chain of survival for OHCA, resulting in a twofold increase in neurological prognosis. Despite younger age and probably better physical shape, off-slope OHCA do not share such ideal chain of survival. Rescuer arrival was longer by 10 min compared to on-slopes cardiac arrest and 8 min compared to other locations. While the level of bystander was the same as the on-slopes situations, the first AED shock was delayed by 12 min compared to ski-slopes and 6 min with the other locations. This is probably the main explanation in the difference of outcomes between these locations. Moreover, initial shockable rhythm was more common in the on-slopes group than in the two others. This could be explained by the increased difficulty in accessing communication devices (calls are taken with radios off the ski-slopes) and perhaps a lower accessibility of AEDs.

Nevertheless, it is also possible to improve some parts of the survival chain for mountain areas. In the past few years, > 120 mountain shelters in the French Alps have been equipped with AEDs [8]. Recently, it was proposed to use drones to deliver AEDs. It has been demonstrated that

Table 3
Outcomes of cardiac arrest on ski slopes and mountain location compared to other locations in univariate and multivariate analysis.

	ROSC			Survival at hospital discharge			Survival at 30-day		
	n (%)	OR (95% CI)	aOR (95% CI)	n (%)	OR (95% CI)	aOR (95% CI)	n (%)	OR (95% CI)	aOR (95% CI)
On-Slopes (n = 213)	77 (36.1)	1.75 (1.31–2.33)	1.93 (1.11–3.37)	40 (18.8)	2.99 (2.10–4.26)	2.99 (1.64–5.45)	29 (13.6)	2.20 (1.48–3.30)	1.80 (0.96–1.31)
On-Mountains (n = 141)	27 (19.4)	0.72 (0.47–1.10)	0.96 (0.43–2.16)	10 (7.1)	0.99 (0.51–1.89)	1.47 (0.57–3.80)	8 (5.7)	0.84 (0.41–0.73)	0.95 (0.33–2.70)
Other Locations	2157 (23.3)	Reference	Reference	662 (7.2)	Reference	Reference	616 (6.7)	Reference	Reference

On-slopes: cardiac arrest on ski-slopes; On-mountains: cardiac arrest on mountainous area off ski slopes; Other locations: at home, public place, public highway, medical establishment, at work, other.

Abbreviation: ROSC: return of spontaneous circulation.

this technique is both feasible and cost effective. A randomized controlled trial showed that the use of drones in mountainous areas reduced the treatment-free interval in search and rescue operations with telemedical support [9]. It appears necessary to evaluate this technique of AED delivery in mountain conditions for cardiac arrest patients. This technology needs to be improved and more evaluated for use in everyday practice [10–12]. In the same way, with technological minimization, we could imagine that mountain guides bring with them the smallest AED in their bags when they support novices in the mountains. However, our findings indicate that cardiac arrests in mountainous areas were more often attributable to traumatic circumstances. It is widely acknowledged that traumatic cardiac arrests lead to poorer outcomes [13]. It was also a significant negative parameter in our multivariate model. This could explain the lower outcomes and lower proportion of shockable rhythms in the on-mountains group. Finally, it was shown that the quality of CPR could be reduced by hypoxia and the impact on the physical strain at high altitude [14]. Use of mechanical chest compression devices at high altitude has been validated and could be proposed to increase CPR quality in these specific circumstances [15]. These results are consistent with two other observational studies about OHCA in mountainous areas [16,17]. With these observations, future research should focus on AED accessibility and the implementation of mechanical CPR to try to improve outcomes.

This paper did not exclusively focus on mountain cardiac arrests during winter but also covers other seasons. Over the last decade, the practice of summer mountain sports and extreme activities (such as base-jumping) has been on the rise. Excluding resort ski areas, both trauma- and non-trauma related deaths were more frequent in activities such as hiking, mountaineering, ski touring, and paragliding [19]. However, the most lethal sports were base-jumping, microlight flying, and white-water sports [19]. Regarding on-slope activities during the summer, we have observed an increase in mountain biking practices in the past few years, accompanied by a rise in related traumas. These shifts in practices should be considered in the future.

With 213 OHCA on ski-slopes and 141 OHCA in mountainous areas, this is the largest observational study published to date. This result permitted the inclusion, since 2015, of two new locations (on-slopes cardiac arrest, on-mountains cardiac arrest) in the RENAU Network Cardiac Arrest Registry. This emphasizes again the importance of registries and their implementation to provide direct feedback to each health professional involved in the management of OHCA. That is why we added in the supplementary analysis some data for each county and for each city/ski resort. This provides to bring to light some hotspots where cardiac arrests, on slopes and on mountainous areas, were more frequent. Due to the enormous variety of locations of OHCA and outcome survival depending strongly on the context, geographical analysis is essential to improve outcomes from OHCA [20].

4.1. Limitations

This study has several limitations. While it constitutes an important database, there were instances of missing data that could affect the analysis, and these missing data were not replaced. However, the registry was completed prospectively after each intervention by the attending physician, and the absence of unreported data was retrospectively verified by dedicated research teams at each call center within the Northern French Alps Emergency Network (RENAU). Moreover, in this observational study, we did not include parameters with excessively high rates of missing data. For transparency, the number of missing data points for each variable is available in Appendix 4. Additionally, it is important to note that these results are specific to the French Alps, representing a regional registry, and may not be representative of other mountain ranges. We did not account for avalanche deaths in our analysis, and therefore, we were unable to determine if traumatic deaths were a result of avalanches. These specific circumstances should

be given greater consideration in future research. Finally, the challenge of accurately classifying on-slope and off-slope cardiac arrests may introduce a misclassification bias that could impact the results. Nevertheless, our findings are in line with previous studies on this topic, which bolsters the confidence in the quality of our data.

5. Conclusion

For out-of-hospital cardiac arrests in mountainous areas, we identified two distinct populations with different outcomes: on-slope cardiac arrests showed a 30-day survival improvement with favorable neurological outcomes, whereas cardiac arrests occurring outside the ski slopes did not demonstrate any improvement in neurological outcome at 30 days. This discrepancy may be attributed to lower automated external defibrillator accessibility, longer intervention delays, and more traumatic circumstances. This emphasizes the need for innovative solutions to be developed to improve outcomes.

CRedit authorship contribution statement

N. Segond: Writing – original draft, Methodology, Formal analysis, Conceptualization. **D. Viglino:** Writing – review & editing, Validation, Supervision, Methodology, Conceptualization. **H. Duhem:** Writing – review & editing, Conceptualization. **C. Vigneron:** Writing – review & editing, Conceptualization. **C. Vallot:** Writing – review & editing, Resources, Project administration. **V. Brenckmann:** Writing – review & editing. **M. Blancher:** Writing – review & editing. **S. Versini:** Writing – review & editing. **A. Serruys:** Writing – review & editing. **D. Savary:** Writing – review & editing. **A. Bellier:** Writing – review & editing, Validation, Supervision, Formal analysis. **G. Debaty:** Writing – review & editing, Validation, Supervision, Conceptualization.

Declaration of competing interest

The authors have no conflicts of interest to declare.

Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.ajem.2024.04.017>.

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