



Major regional disparities in outcomes after sudden cardiac arrest during sports

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Aims

Characteristics of sudden cardiac arrest (SCA) during sports offers a novel (and unexplored) setting to assess factors associated with disparities in outcomes across regions.

Methods and results

From a prospective 5-year community-based French registry concerning SCA during sports in 10–75 year-olds, we evaluated whether outcomes differed significantly between geographic regions. We then determined the extent to which variations in community-related early interventions were associated with regional variations in survival. Among 820 SCA cases studied, overall survival at hospital discharge was 15.7% (95% confidence interval, 13.2–18.2%), with considerable regional disparities (from 3.4 to 42.6%, $P < 0.001$). Major differences were noted regarding bystander initiation of cardiopulmonary resuscitation (15.3–80.9%, $P < 0.001$) and presence of initial shockable rhythm (28.6–79.1%, $P < 0.001$), with higher values of these being associated with better survival rates. The proportion of survivors with favourable neurological outcome at discharge was fairly uniform among survival groups (CPC–1/2, varying from 77.4 to 90.0%, $P = 0.83$). No difference was observed regarding subjects' characteristics and circumstances of SCA occurrence, including delays in resuscitation (collapse-to-call period). With a comparable in-hospital mortality ($P = 0.44$), survival at hospital discharge was highly correlated with that at hospital admission (regional variations from 7.4 to 75.0%, $P < 0.001$).

Conclusion

Major regional disparities exist in survival rates (up to 10-fold) after SCA during sports. SCA cases from regions with the highest levels of bystander resuscitation had the best survival rates to hospital admission and discharge.

Keywords

Cardiopulmonary resuscitation • Defibrillation • Bystander • Delay • Education • Basic life support

Introduction

Despite a number of recent encouraging reports, overall survival rates after out-of-hospital sudden cardiac arrest (SCA) in the general community have remained essentially unchanged over recent decades.^{1–3} This somewhat disappointing observation raises questions concerning the effectiveness of individual factors, community interventions such as public education in basic life support and public access defibrillation, as well as medical care provided both on site and during hospitalization.⁴

Consideration of regional variations in survival rates after SCA has been recently proposed as an interesting tool for identifying those factors which most influence survival.^{5–7} However, the interpretation of such regional variations has remained particularly challenging in the setting of SCA in overall population, mainly due to major heterogeneities in population characteristics, circumstances of occurrence, as well as medical management between regions.^{4,5,8,9}

We have recently described the first comprehensive assessment of SCA during sports activity in the general population.¹⁰ Through

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a national prospective 5-year study carried out in France, we have reported characteristics of SCA during competitive and recreational sport activities. From these first descriptive data, it appeared that SCA during sports activities had a remarkable uniformity across regions, with regard to population characteristics and circumstances of occurrence. This also offers an opportunity to capture and analyse crucial data (e.g. collapse-to-call period of time) not previously reported.³ Taken together, sports-related SCA appears to be a particularly good circumstance for regional analysis of survival. Moreover and at the best of our knowledge, functional neurological outcomes of survivors, a key factor in assessing the effectiveness of resuscitation, has not been integrated into such approaches.^{5,6}

In the present paper, after having documented major regional survival disparities in the setting of sports activities, we identified the extent to which conventional evidence-based individual factors, known to be associated with survival, were distributed among different regions. Moreover, we assessed if functional outcome varied between regions with differing rates of survival.

Methods

Study setting

The study design has been previously described.¹⁰ Briefly, this prospective study was carried out according to Utstein guidelines,¹¹ between April 2005 and April 2010 in France. This study aimed to evaluate the circumstances and characteristics of SCA during sports in the general population aged 10–75 years, with a specific focus on survival and associated factors. The project was commissioned in 2004 by the Sports and Health French Ministry and carried out by the French Institute of Health and Medical Research (INSERM), both organizations funding the research. Sixty out of the 96 French administrative regions participated in the study (see Appendix for Participating Centres).

Sudden cardiac arrest in the setting of sport activities was defined as death occurring during or within 1 h of cessation of sports activity.^{12–14} In the majority of cases, it presented as an unexpected collapse during physical exertion. Traumatism-related SCA were excluded, except for cases of commotio cordis. Subjects aged between 10 and 75 years were included in the study, since the context of physical activity can be difficult to assess in the very young and those of more than 75 years rarely participate in sports. To optimize case detection, we used two complementary and independent sources: emergency medical services (EMS) and continuous Web monitoring of more than 250 newspapers. Manual checking of these reports was performed to identify verifiable sports-related SCA in 10–75 year-olds and when not already been notified to us via EMS, complementary information was then obtained via written accounts and/or telephone interviews with the local emergency team.

We obtained close collaboration from EMS as well as from the intensive care units throughout the 60 participating regions. In France, a unique EMS exists—Service d'Aide Médicale Urgente (SAMU)—which is very homogeneously distributed/implemented and provides standardized care via common guidelines/protocols across regions.^{15,16} The SAMU is a special unit within a hospital designed to receive and dispatch urgent medical calls. It coordinates paramedics and special units distributed evenly throughout each region.¹⁵ Paramedics are dispatched and usually arrive first on the scene to initiate chest compression and ventilation, rhythm assessment, as well as prompt defibrillation (when appropriate). Then, a medical team is systematically dispatched in an ambulance. This team includes at least one physician specialized in emergency medicine (according to the European Society of Cardiology guidelines),

one nurse, and one ambulance driver and initiates advanced life support, including intravenous lines, mechanical ventilation, and inotropic support. Patients in whom restoration of spontaneous circulation is achieved are then referred to a tertiary centre with an intensive care unit and coronary intervention facilities available 24 h a day, 7 days a week. In patients without an obvious non-cardiac cause of SCA, it was recommended that the patient be taken to the cardiac catheterization laboratory, regardless of clinical and ECG findings, for a coronary angiogram.^{17,18} Patients are then admitted to the intensive care unit for supportive treatment, which may include therapeutic hypothermia.¹⁹

Collected data

Variables collected for each case report file include subject's characteristics (demographics, known heart disease, cardiovascular risk factors), setting and circumstances of collapse (setting and time of occurrence, presence of one/multiple witnesses, collective or individual sport practice, leisure or competitive event, level of exercise estimated at the time of collapse), basic and advanced life support [initiation of cardiopulmonary resuscitation (CPR), public use of automated external defibrillator (AED), and collection of the different delays with a particular attention on the collapse-to-call delay, delivered cardiac rhythm recorded, delivered defibrillator shocks], and vital as well as functional outcomes [survival at hospital admission and hospital discharge, and neurological prognosis using the Cerebral Performance Category (CPC) score]. Data regarding vital and neurological status at hospital discharge were recorded by the INSERM U970. Files were consecutively and regularly reviewed (every 6 months) by an independent Events committee.¹⁰

To assess community-based strategies for public education in the 'Chain of Survival', particularly CPR, a comprehensive assessment of specific programmes over all the regions was carried out continuously over the 2005–10 study period by a specific working group, blinded to regional data on survival. To analyse, three categories of training sessions were identified: (i) official national courses (2-day session) leading to a specific certification form [Premier Secours Civique Niveau 1 (PSC-1), Attestation de Formation aux Premiers Secours and Sauveteur Secouriste du Travail (SST)], carried out under the auspices of the Ministère Français de l'Intérieur by five governmental agencies (Croix Rouge Française, Fédération Nationale des Sapeurs Pompiers, Fédération Nationale de la Protection Civile, and the Institut National de Recherche et de Sécurité and the Caisse Nationale de l'Assurance Maladie des Travailleurs Salariés); (ii) official national short-training session, called initiation (3 h session), conducted throughout the French territory under the Journée d'Appel à la Défense (JAPD) (during a 1-day session focused on civil education mandatory since 31 December 2004 for all citizens 18 years of age) and the Initiation aux Premiers Secours (IPS) (Croix Rouge Française, Fédération Nationale des Sapeurs Pompiers, Fédération Nationale de la Protection Civile). No formal certification is delivered; (iii) finally, local (region specific) initiatives training sessions carried out by local authorities (various private and/or public institutional agencies) with very short, interactive, and repeated sessions. This training is advertised in the local media and conducted by a number of non-profit organizations. For each of these categories, the total numbers of trained persons by 100 000 inhabitants by region were quantified.

Statistical analysis

This report was prepared in compliance with the STROBE checklist for observational studies.²⁰ Characteristics of SCA were described as mean \pm SD, proportions (%), and median and inter-quartile ranges as appropriate. Survival rates at hospital admission and discharge, as well as proportion of favourable neurological outcome at discharge (CPC

score 1 and 2) were determined for each region and their 95% confidence interval (CI) was calculated.

Regions were sorted according to SCA survival rates at hospital discharge. Using arbitrary cut-offs of 10, 20, and 40%, four groups of survival at discharge were identified (low, 0–10%; medium–low, 10–20%; medium–high, 20–40%, and high, more than 40% of survival at hospital discharge), and their mean survival rates and 95% CI were assessed at hospital admission, during the in-hospital period, and at hospital discharge. Data on subjects' characteristics, setting and circumstances of occurrence, basic life support initiation by bystander, advanced life support, and outcomes were described through the four survival groups. We specifically focused on the five most commonly recognized factors associated with survival: presence of witness, CPR initiation by bystander, presence of initial shockable rhythm, defibrillation delivery, as well as delays of intervention (collapse-to-call EMS, collapse-to-EMS arrival, and collapse-to-defibrillation).¹ Qualitative variables were compared using the χ^2 test, and quantitative variables using analysis of variance or the Kruskal–Wallis test for comparisons across multiple groups. Difference in survival across regions was also tested using a generalized linear model.

All tests were two-tailed, and $P < 0.05$ was considered indicating statistical significance. All data were analysed at INSERM, Unit 970, Cardiovascular Epidemiology and Sudden Death, Paris, using STATA software version v11.0 (Lakeway Drive, TX, USA). The authors had full access to data and designed the statistical analysis, and had final responsibility

for the decision to submit the manuscript for publication and vouch for the accuracy and completeness of the data and the analyses.

Results

Over the 5-year study period, 820 SCA during sports were recorded and their general characteristics have been previously reported.¹⁰ Overall, the mean age of subjects was 46 ± 15 years (range 11–75), with a striking male predominance (male/female ratio of 20:1). While the majority (88.3%) of subjects did not have any previous history of heart disease and/or more than one cardiovascular risk factor, 3.8% had a known history of coronary heart disease. Half of the SCA (52.0%) occurred in sports facilities (such as a gymnasium or a stadium) in the presence of at least one witness in almost all cases (99.8%). Bystander CPR was initiated in 30.7% of cases. The initial cardiac rhythm was ventricular fibrillation or pulseless fast ventricular tachycardia in 46.7% of cases, and defibrillation was attempted in 61.1%. The median collapse-to-call, collapse-to-CPR initiation, and collapse-to-first defibrillator shock times were 2.0 (0.5–4.5), 4.8 (1.2–8.5), and 12.5 (10.5–15.5) min, respectively. Of the 820 cases, 253 (30.8%) subjects were admitted to hospital, and 128 were alive at hospital discharge, giving an overall survival rate at hospital discharge of 15.7% (95% CI 13.2–18.2).

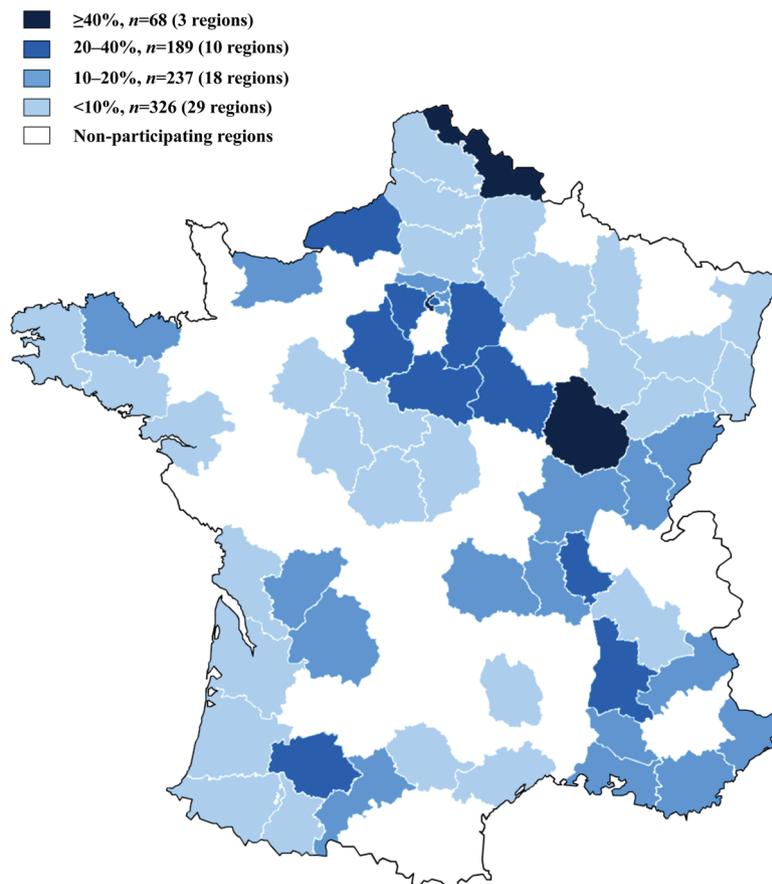


Figure 1 Survival rates at hospital discharge in the participating regions.

Marked disparities in survival at hospital discharge were observed among the 60 French regions, with rates varying from 0 to 43.8% (and from 3.4–42.6% for survival groups). No apparent specific geographic distribution of best survival regions throughout the national area was noted (Figure 1). According to different groups of survival (low, 0–10%; medium–low, 10–20%; medium–high, 20–40%, and high, more than 40% of survival at hospital discharge), we analysed (i) subjects' characteristics, setting, and circumstances of occurrence, (ii) basic life support provided by bystander and advanced life support provided by EMS, as well as (iii) vital and functional outcomes.

Data regarding subjects' characteristics, setting, and circumstances of occurrence are summarized in Table 1. Overall, we noted no significant differences in these characteristics, across the different groups of survival. This included mean age, gender, history of heart disease, and/or presence of more than one cardiovascular risk factor. Moreover, location of occurrence (sport facilities vs. non-sport facilities), competition setting, presence of witness(es), and type of sports (individual vs. team sports) did not differ significantly between groups. Finally, time of occurrence and the frequency of vigorous levels of exercise were not statistically different between groups of survival.

Details on basic and advanced life support provided by witness(es) and EMS on the field are reported in Table 2. The likelihood of bystander to initiate or not CPR markedly differed between groups (initiated in 15.3% of case in the low-survival group, compared with

80.9% in the high-survival group, $P < 0.001$) (Figure 2A). Accordingly, delay from collapse to CPR initiation was significantly shorter in groups with better survival ($P = 0.02$). On the other hand, we observed that the promptness of witnesses calling for EMS was remarkably similar across groups of survival, with a median delay between collapse and call to EMS varying from 2.0 to 2.2 min ($P = 0.35$) (Figure 2B). We denoted only five cases of defibrillation by public witnesses (not related to EMS), before EMS arrival, with no significant difference among survival groups (from 0.3 to 1.5%, $P = 0.74$) (Figure 3A). The presence of an initial shockable rhythm at the time of assessment by the EMS team was much more common in the high-survival group (from 28.6 to 79.1%, $P < 0.0001$) (Figure 3A). The delay for EMS arrival on site was not statistically different across survival groups, from 10.4 (7.9–14.3) to 11.2 min (8.4–14.5) ($P = 0.53$) (Figure 2B). The mean number of shocks delivered by EMS was of 5.3 ± 4 (range 1 to 19), and extra-corporeal membrane oxygenation system was used in the field in two cases, with no significant variation across groups.²¹

Data on outcomes are reported in Table 2. Major disparities were observed at hospital admission between groups, from 7.4 to 75.0% ($P < 0.001$) (from 0 to 78.1% at the region). Of the 253 subjects who were alive at hospital admission, no significant difference was observed regarding in-hospital mortality, reported between 43.1% (95% CI, 29.5–56.7) and 56.3% (95% CI, 44.8–67.9) ($P = 0.44$).

Table 1 Subject characteristics, setting, and circumstances of sudden cardiac arrest occurrence according to survival rate grouping at hospital discharge

Survival rates at hospital discharge	Low, 0–10%	Medium–low, 10–20%	Medium–high, 20–40%	High, ≥40%	P-value
Number of subjects	326	237	189	68	
Number of regions	29	18	10	3	
Areas (km ²)	182 523	91 510	50 701	14 682	
10–75 year population	13 630 400	10 252 000	7 745 240	2 840 400	
Subject's characteristics					
Age (year), mean ± SD (IQR)	46.7 ± 15 (37–58)	46.2 ± 13 (38–57)	46.5 ± 15 (36–58)	46.3 ± 16 (38–59)	0.98
Male sex	310 (95.1)	226 (95.4)	177 (93.7)	64 (94.1)	0.86
History of heart disease and/or >1CVRF ^a	35 (11.3)	28 (12.0)	22 (11.6)	9 (13.2)	0.97
Setting					
Public sport facilities	166 (51.0)	125 (53.4)	98 (51.9)	37 (54.4)	0.92
Competitive setting	54 (16.6)	37 (16.3)	30 (17.0)	12 (17.7)	0.99
Presence of witness(es)	303 (93.2)	217 (91.9)	174 (92.5)	62 (92.5)	0.80
Team sport activity	101 (31.0)	83 (35.0)	67 (35.4)	22 (32.4)	0.68
Circumstances of occurrence					
Time of day (6 a.m.–6 p.m.)	252 (77.3)	192 (81.0)	150 (79.4)	52 (76.5)	0.71
Week-end	134 (41.1)	95 (40.1)	76 (40.2)	31 (45.6)	0.87
Summer	97 (29.7)	66 (27.8)	57 (30.1)	23 (33.8)	0.50
Vigorous exercise level	124 (38.5)	99 (42.3)	73 (38.8)	26 (38.2)	0.83

Data are presented as no. (%) unless otherwise specified.

^aCardiovascular risk factor included known/treated diabetes mellitus, dyslipidaemia, systemic hypertension, obesity, current smoker, and family history of premature coronary heart disease.

Data were missing on history of known heart disease (for 8 subjects), cardiovascular risk factors (11), level of exercise (8).

Percentages were calculated on the basis of the total number of known events.

CVRF, cardiovascular risk factor; IQR, inter-quartile range; SD, standard deviation.

Table 2 Basic life support, advanced life support, and in-hospital outcomes (survival and neurological) according to survival rate grouping at hospital discharge

Survival rates at hospital discharge	Low, 0–10%	Medium–low, 10–20%	Medium–high, 20–40%	High, ≥40%	P-value
Basic life support					
Collapse-to-call received delay	2.0 (0.7–4.6)	2.2 (0.5–4.5)	2.1 (2.6–4.8)	2.0 (0.7–4.2)	0.35
Bystander CPR	50 (15.3)	62 (26.2)	85 (45.0)	55 (80.9)	<0.001
Collapse-to-start CPR delay	6.1 (4.5–8.8)	4.7 (1.0–8.7)	3.1 (0.7–6.0)	2.5 (0.6–4.5)	0.02
Public use of AED	1 (0.3)	2 (0.9)	1 (0.5)	1 (1.5)	0.74
Advanced life support					
Collapse-to-EMS arrival delay	11.2 (8.4–14.5)	10.6 (8.5–14.2)	10.4 (7.9–14.3)	10.9 (8.2–14.4)	0.53
Shockable rhythm	92 (28.6)	107 (45.9)	125 (67.2)	53 (79.1)	<0.001
Collapse-to-defibrillation delay	14.2 (10.7–15.8)	13.2 (9.8–14.7)	12.7 (8.9–13.8)	12.1 (8.7–13.7)	0.15
Collapse-to-ROSC delay	28.4 (20.6–34.2)	29.1 (21.2–33.7)	27.5 (19.8–32.5)	25.3 (18.2–30.8)	0.51
Outcomes					
Survival at hospital admission	7.4 (4.5–10.2)	30.0 (24.1–35.8)	56.6 (49.6–63.7)	75.0 (64.7–85.3)	<0.001
Survival at hospital discharge	3.4 (1.4–5.3)	13.1 (8.8–17.4)	30.2 (23.6–36.7)	42.6 (30.9–54.4)	–
In-hospital mortality	54.2 (34.2–74.1)	56.3 (44.8–67.9)	46.7 (37.3–56.2)	43.1 (29.5–56.7)	0.44
Functional (favourable)	90.0 (71.4–100.0)	77.4 (62.7–92.1)	82.1 (72.1–92.2)	82.8 (69.0–96.5)	0.83

Data are presented as no. (%) and median (IQR), min for delays. Survival and mortality rates as well as functional outcome are presented as proportion and 95% CI.

Data were missing on the presence of witness (4), monitored rhythm (12), public use of AED (24).

Percentages were calculated on the basis of the total number of known events.

AED, automatic external defibrillator, CI, confidence interval; CPR, cardiopulmonary resuscitation; ROSC, return of spontaneous circulation.

Finally, survival at hospital discharge (ranged from 3.4 to 42.6%, $P < 0.001$) was highly correlated with survival to hospital admission (Figure 3B). The test of the region survival variance component in the model was found highly significant (overall $P < 0.001$, as well as the Tukey–Kramer adjustment for any survival group-to-group comparison $P < 0.001$). Vital and functional (neurological) outcomes across the four groups of survival are schematized in Figure 4. The majority of these patients (103 out of the 126 for whom neurological assessment was established, 81.7%) had a favourable neurological outcome (defined as a CPC scoring grade 1 or 2). Favourable neurological outcome among survivors varied between 77.4 and 90.0% ($P = 0.83$) across survival groups.

From comprehensive evaluation of education programmes to ‘Chain of Survival’, we observed that regions with better survival rates had significantly higher proportion of the population educated in basic life support ($P < 0.0001$). Whereas national education of the population was highly homogeneous among regions (around 11 500 trained persons per 100 000 inhabitants during the 5-year period), major disparities in local education levels were noted, varying from 758 to 18 833 cumulated trained persons per 100 000 inhabitants.

Discussion

In the setting of sports activities, we demonstrate here that there may be marked heterogeneity in survival rates between regions (up to 10-fold), with survival rates of more than 40% in numerous regions, and <10% in many others. The particular setting of sports-related SCA allowed a better understanding of factors most associated with survival. Our results emphasized the extent to which

disparities in survival at hospital discharge principally are associated with pre-hospital factors in the very early period after SCA, even before the arrival of EMS, and particularly underlined the crucial importance of CPR delivery by the witness in the field. Finally, our data show that better survival in this setting was not obtained at the expense of a greater proportion of subjects with an adverse neurological outcome. Taken together, this should guide identification of effective interventions that are used in some communities but have not been implemented in others, including active and repeated active public education in basic life support, which might increase the likelihood of CPR initiation by witness(es) on site.

Our study showed similar disparities in survival rates across regions for SCA occurring after sports activities, as others have shown for SCA of any type. We might expect that survival rates after sports-related SCA would be relatively uniform across France, given the similarities in subjects’ characteristics and circumstances of occurrence, as well as the known homogeneous EMS coverage in this setting (supported by the high similarity of times to arrival of EMS among regions in France).¹⁶ Nevertheless, the considerable variations in bystander resuscitation rates across regions were associated with significant variations in survival rates, in this setting. Finally, our results emphasize the contrast between the relative uniformity of in-hospital outcomes (vital as well as functional) and the marked variability across regions of events during the pre-hospital phase, well before hospital admission.

The unique setting of SCA occurring during and after sports activities allows relatively uniform data collection, more than in the setting of all-coming SCA; for example, information regarding the delay between collapse and call to EMS, since, it has been hypothesized that public education could improve outcome after SCA through

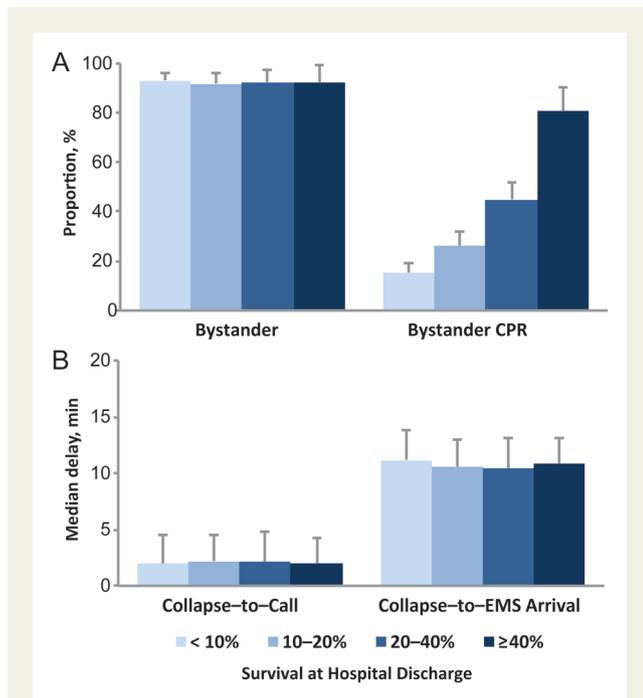


Figure 2 Factors associated with survival—proportion of bystander presence, cardiopulmonary resuscitation initiation by bystander, as well as collapse-to-call and collapse-to-emergency medical services arrival delays, according to rates of survival at hospital discharge. Analysis across the four groups of survival demonstrate that, despite a very high and almost constant presence of bystander, the rate of cardiopulmonary resuscitation initiation by bystanders on the scene is highly variable among regions (A), whereas the promptitude of bystander to call emergency medical services is highly homogeneous. Finally, the delay of emergency medical services intervention appears highly homogeneous in the setting of sudden cardiac arrest during sports activities (Panel B).

better awareness of early alert, and earlier activation of EMS.²² Our results emphasize the urgent need to focus on the very early period after SCA, which includes CPR initiation by a bystander, and do not support the theory that the potential benefit of CPR initiation is actually linked to an earlier call to EMS by bystanders.³ As suggested here, effective CPR can extend the window of opportunity for successful defibrillation.^{23–25} Drezner et al.^{13,26,27} reported an improved survival rate for young athletes with SCA if prompt CPR and early defibrillation are achieved, with up to 64% alive at hospital discharge. These findings have implications for pre-hospital emergency care, but principally to policy making authorities to promote education of the community in basic life support, in considering that SCA should be considered a treatable condition. Of note, only one-third of witnessed SCA received bystander CPR, suggesting that even better results can still be achieved.²⁸ Therefore, ongoing efforts are necessary to encourage the public to be ready, willing, and able to provide CPR when appropriate and necessary.^{29–32}

The very low AED use by public bystanders in our study appears to be the result, at least in part, of limited AED availability (as AED availability in stadium or other sporting facilities is not yet mandatory in France, with no clear recommendations, in contrast to the case of

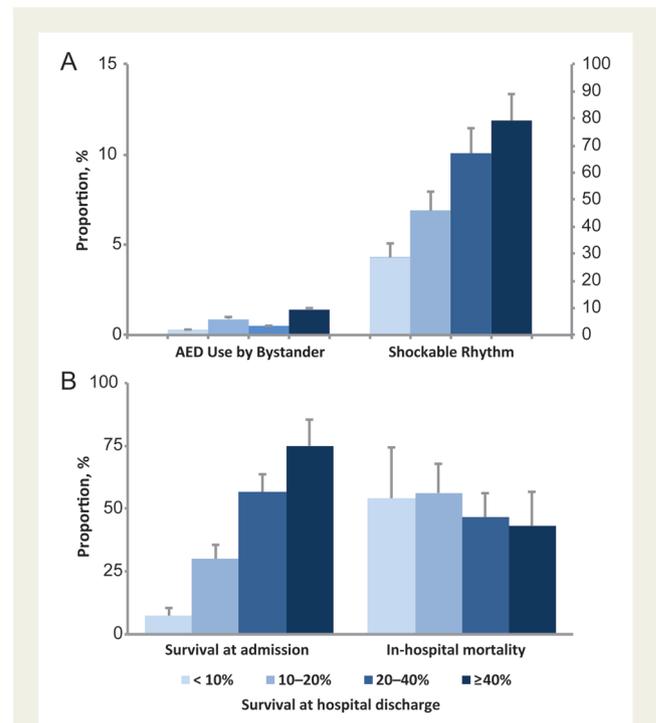
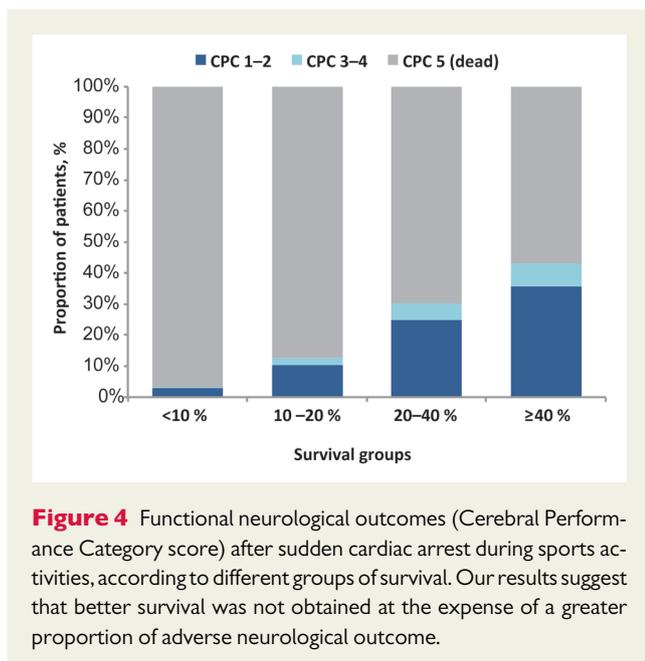


Figure 3 Factors associated with survival—proportion of automated external defibrillator use by bystander, shockable rhythm, as well as survival at hospital admission and in-hospital mortality, according to rates of survival at hospital discharge. Analysis across the four groups of survival demonstrate that the rate of public automated external defibrillator use is dramatically low throughout the four groups of survival, although major differences exist in the proportion of shockable rhythm (A). In-hospital mortality is not significantly different across the four groups of survival, and finally, survival at hospital discharge is highly correlated with survival to hospital admission (B).

the United States).^{33,34} Despite this low AED use by bystanders, several regions had very high survival rates, and a wider use of AED in this specific setting of sport practice could allow even higher survival rates, beyond the current 40% survival we observed in such regions, at hospital discharge (given the well-known benefits of early defibrillation).^{4,29} Our systematic evaluation demonstrated a very high degree of heterogeneity in terms of community-based educational programmes, particularly from local initiatives. The Côte d'Or region in Burgundy and the Nord region, which had the highest survival rates among all regions, have been the two most active French areas in terms of public education, with the first AEDs deployments and associated community-based sessions which started in 1993, 14 years before the registration of public AEDs in France. According to the known key role of CPR initiation as well early defibrillation, our data emphasized the substantial room for improvement of public knowledge and attitudes towards basic life support.³⁵

Although identification of high-risk subjects is beyond the scope of our paper, we hope that these results from our registry are unique and may contribute to a better understanding in the future in identification of high-risk competitive and leisure athletes,



particularly among middle-age men.^{36–45} We note the striking male predominance in sports-related SCA in this series. This is not simply due to greater male participation; for example, considering the five most common sports in which sports-related SCA occurred, 36% of participants across France are female (as judged from those with a licence in those sports) whereas only 5% of sports-related in those sports occurred in females. Finally, although regular physical activity benefits cardiovascular health, sport, particularly when practiced vigorously, has been shown to increase the risk of dying suddenly during or shortly after exercise (compared with at rest).^{46–48} This should be considered in interpreting our relatively high proportion of SCA cases during vigorous exertion.

Besides the survival rate, neurological outcome of survivors is also a key factor in determining successful resuscitation. To the best of our knowledge, no data have been published on the neurological prognosis associated with regional survival disparities such as those noted in this study.^{5,6} In our study, the proportion of survivors with good cerebral outcomes was highly similar across regions. Thus, high levels of survival to hospital discharge in particular regions are indeed accompanied by good neurological outcomes, rather than producing survivors with poor cerebral performance.

We acknowledge some limitations. First, the effectiveness of CPR was not assessed in our study, and we are aware of the difficulty of providing good quality CPR and of the variations in CPR ‘quality’ among individuals. However, poor quality bystander CPR (hypothesized in a significant proportion of cases) would only underestimate any observed association between early initiation of CPR and survival. Secondly, we used this very particular situation (SCA during sports in France) as a model to understand the importance of early stages in post-SCA resuscitation and care; we agree that some specificities of the EMS and hospital health systems in France (with a protocolized national approach) might mean that our results are not necessarily applicable to all other countries. Thirdly, the study was on a voluntary basis of each region, and the extent to which sports-related SCA burden differ among the non-participating regions

remains. However, the possibility of selection bias has been rejected by the presence of similar incidence rates over all the four survival groups. Finally, our observational approach does not allow an assessment of the efficacy of community-based measures. Thus, we were only able to demonstrate their association with survival without establishing a true causal link.

In summary, major regional disparities exist in survival after SCA during sports activities. Survival may be particularly high, up to 40%, with favourable neurological outcomes in most of the survivors. This heterogeneity in survival rates at hospital discharge across regions seems to reflect differences in the very early phases of resuscitation, even before the arrival of EMS to the site of the SCA. Our results highlight the key role of bystanders in providing immediate basic life support.

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Conflict of interest: none declared.

Appendix: Participating centres

The investigators and coordinators participating in the study were as follows:

02 Aisne, Dr F. Degrootte; 05 Hautes-Alpes, Dr M. Tashan; 06 Côte d’Azur, Dr D. Grimaud; 13 Bouches-du-Rhône, Dr V. Vig; 14 Calvados, Dr D. Bonnieux; 16 Charente, Dr R. Loyant; 17 Charente-Maritime, Dr F. Mounios; 18 Cher, Dr F. Bandaly; 21 Côte-d’Or, Dr M. Freysz; 22 Côtes-d’Armor, Dr C. Hamon; 24 Dordogne, Dr M. Gautron; 25 Doubs, Dr M.C. Maillot; 26 Drôme, Dr C. Zamour; 28 Eure-et-Loir, Dr N. Letellier; 29 Finistère, Dr C. Lazou; 31 Haute-Garonne, Dr J.L. Ducasse; 32 Gers, Dr J.M. Guez; 33 Gironde, Dr M. Thicoipe; 34 Hérault, Dr P. Benatia; 36 Indre, Dr L. Soulat; 37 Indre-et-Loire, Dr J. Fuscuardi; 38 Isère, Dr K. Berthelot; 39 Jura, Dr A. Elisseeff; 40 Landes, Dr R. Ricard; 41 Loir-et-Cher, Dr S. Randriamalala; 42 Loire, Dr T. Guerin; 44 Loire Atlantique, Dr V. Debierre; 45 Loiret, Dr S. Narcisse; 48 Lozère, Dr M. Chassing; 51 Marne, Dr A. Léon; 52 Haute-Marne, Dr J. Milleron; 55 Meuse, Dr M. Vedel; 56 Morbihan, Dr F. Charland; 59 Nord, Dr N. Benameur; 60 Oise, Dr T. Ramaherison; 62 Pas-de-Calais, Dr L. Hapka; 63 Puy-de-Dôme, Dr J. Meyrieux; 64 Pyrénées-Atlantiques, Dr I. Pouyanne; 65 Hautes-Pyrénées, Dr J. Khazaka; 67 Bas Rhin, Dr J.C. Bartier; 68 Haut-Rhin, Dr B. Goulesqueb; 69 Rhône, Dr P.Y. Gueugniaud; 70 Haute-Saône, Dr T. El Cadi; 71 Saône-et-Loire, Dr B. Girardet; 72 Sarthe, Dr C. Savio; 75 Paris, Dr D. Jannièrre; 76 Seine-Maritime, Dr B. Dureuil; 77 Seine et Marne, Dr J.Y. Le Tarnec; 78 Yvelines, Dr C. Cazenave; 80 Somme, Dr C. Ammirati; 81 Tarn, Dr M.G. Vaissière; 83 Var, Dr J.J. Raymond; 84 Vaucluse, Dr P. Olivier; 88 Vosges, Dr H. Tonnelier; 89 Yonne, Dr M. Duche; 90 Territoire-de-Belfort, Dr A. Kara; 92 Hauts-de-Seine, Dr M. Baer; 93 Seine-Saint-Denis, Dr F. Adnet; 94 Val-de-Marne, Dr C. Vallier; 95 Val-d’Oise, Dr C. Ramaut.

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