



## Clinical paper

## Cardiopulmonary resuscitation duration and survival in out-of-hospital cardiac arrest patients<sup>☆</sup>



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## ABSTRACT

**Aim:** Relationship between cardiopulmonary arrest and resuscitation (CPR) durations and survival after out-of-hospital cardiac arrest (OHCA) remain unclear. Our primary aim was to determine the association between survival without neurologic sequelae and cardiac arrest intervals in the setting of witnessed OHCA.

**Methods:** We analyzed 27,301 non-traumatic, witnessed OHCA patients in France included in the national registry from June 1, 2011 through December 1, 2015. We analyzed cardiac arrest intervals, designated as no-flow (NF; from collapse to start of CPR) and low-flow (LF; from start of CPR to cessation of resuscitation) in relation to 30-day survival without sequelae. We determined the influence of recognized prognostic factors (age, gender, initial rhythm, location of cardiac arrest) on this relation.

**Results:** For the entire cohort, the area delimited by a value of NF greater than 12 min (95% confidence interval: 11–13 min) and LF greater than 33 min (95% confidence interval: 29–45 min), yielded a probability of 30-day survival of less than 1%. These sets of values were greatly influenced by initial cardiac arrest rhythm, age, sex and location of cardiac arrest. Extended CPR duration (greater than 40 min) in the setting of initial shockable cardiac rhythm is associated with greater than 1% survival with NF less than 18 min. The NF interval was highly influential on the LF interval regardless of outcome, whether return of spontaneous circulation ( $p < 0.001$ ) or death ( $p < 0.001$ ).

**Conclusion:** NF duration must be considered in determining CPR duration in OHCA patients. The knowledge of (NF, LF) curves as function of age, initial rhythm, location of cardiac arrest or gender may aid in decision-making vis-à-vis the termination of CPR or employment of advanced techniques.

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## Introduction

Sudden cardiac arrest accounts annually for 600,000 deaths in industrialized countries. Time to treatment is recognized as a main predictor of survival.<sup>1</sup> Duration of resuscitation efforts is widely recognized as a major determinant of survival after out-of-hospital cardiac arrest (OHCA). Duration of resuscitation may be defined as the sum of two distinct intervals: (1) no-flow ([NF]; interval from collapse to initiation of CPR) and (2) low-flow ([LF]; interval from start of cardiopulmonary resuscitation (CPR) to return of

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**Table 1**

Characteristics of resuscitated OHCA patients, included in the RéAC register.

Variable <sup>a</sup>	(N=27,301)
Median age—(10th–90th percentile)—year	71 (58–82)
Age ≥ 65 year—no. (%)	17,058 (62.5)
Male gender—no. (%)	17,728 (64.9)
Location	
Home—no. (%)	19,977 (73.2)
Other—no. (%)	7209 (26.4)
Sudden death characteristics	
EMS—witnessed arrest—no. (%)	2424 (8.9)
Bystander witness performed CPR—no. (%)	11,900 (43.6)
Initial cardiac rhythm—no. (%)	
Ventricular fibrillation or pulseless ventricular tachycardia	3814 (14.0)
Asystole or pulseless electrical activity	22,007 (80.6)
Time from collapse to arrival of first responders, median (10th–90th percentile)—min	14 (5–37)
Time from collapse to first defibrillation shock, median (10th–90th percentile)—min	14 (5–30)
Time from collapse to start of advanced resuscitation, median (10th–90th percentile)—min	24 (10–50)
Time from collapse to start of CPR; i.e. no-flow duration, median (10th–90th percentile)—min	10 (0–35)
Time from start of CPR to the end of resuscitation efforts (ROSC or withdraw resuscitation) i.e. low flow, median (10th–90th percentile)—min	30 (10–50)
Resuscitation outcomes	
Return of spontaneous circulation—no. (%)	7312 (26.8)
Survival to hospital admission—no. (%)	5378 (19.7)
30 day—survival to hospital discharge	1482 (5.4)
30-day—survival to hospital discharge with CPC 1–2	1249 (4.5)

OHCA denotes out-of-hospital cardiac arrest; EMS denotes emergency medical system, CPR denotes cardiopulmonary resuscitation; CPC denotes Cerebral Performance Categories.

<sup>a</sup> All missing data are <5%.

spontaneous circulation (ROSC) or termination of resuscitation).<sup>2</sup> Relatively few published studies have examined the impact of low-flow and no-flow intervals on clinical outcomes.<sup>1,3,4</sup> However these two factors are widely recognized as the most important variables associated with long-term survival without sequelae.<sup>5</sup> Two recent studies pointed out this correlation, based on nationwide registries.<sup>1,3</sup> The first study demonstrated a very robust correlation between the no-flow (NF) interval and survival status, with a rate of survival less than one percent when duration of no-flow exceeded 14 min.<sup>1</sup> In the second study, the authors suggested a strong association between duration of CPR (low-flow) and rate of ROSC with significant increase in survival when institutionally-imposed duration of CPR (low-flow) exceeded 30 min.<sup>3</sup> The results were similar in the setting of in-hospital cardiac arrest.<sup>5</sup> No systematic studies, however, have evaluated the impact of both NF and LF intervals in terms of survival without sequelae and the interaction of these two time parameters. In fact, one might anticipate that prognosis should be inversely proportional to LF and NF. Clinicians often feel helpless in assessing the appropriate length of resuscitation attempts when considering termination of efforts. Unfortunately, national and international guidelines have not adequately addressed this issue. European Resuscitation Council Guidelines for Resuscitation 2015 state that asystole for more than 20 min in the absence of a reversible cause and with ongoing advanced resuscitation constitutes a reasonable ground for stopping further resuscitation attempts.<sup>6</sup> Other authors have opined that it is reasonable to stop resuscitation after a patient has been in asystole for more than 10 min, if there is no readily identified and reversible cause.<sup>7</sup> A quantitative understanding of the relation between LF, NF and survival may help emergency response teams to evaluate the chance of survival knowing two values (NF, LF), aiding in the decision to terminate cardio-pulmonary resuscitation (CPR) or to implement other strategies, such as extracorporeal resuscitation (ECPR) and/or non-heart beating donor orientation (NHBD).<sup>8,9</sup>

In the current study, our primary aim was to determine the association between survival without neurologic sequelae and values of NF and LF in the setting of witnessed OHCA of medical (non-

traumatic) origin. A secondary aim was to determine the set of values of NF and LF in which CPR may be considered as futile.

## Methods

### Participant selection

Study subjects were selected from RéAC, a large, multicenter observational registry of OHCA in France. All patients of any age who have had an OHCA, regardless of etiology, in which a prehospital medical team is involved, regardless of resuscitation attempts, are included in the RéAC register. RéAC was initiated in 2009 and officially implemented in June 2011 in two university hospitals (Lille and Lyon).<sup>10</sup> The RéAC register is a nonprofit organization directed by a management board.

All EMS centers in France report data to the registry in accordance with the Utstein style.<sup>11</sup> Patients are identified through centralized collection of cardiac arrest flow sheets (i.e., clinical records of the events and treatments administered during CPR). Currently, RéAC catalogs about 70% of all persons who have had an OHCA in France and who were managed by a prehospital medical team. Variables obtained include cardiac arrest circumstances, time delays, and characteristics of the resuscitation attempts, hospital survival and 30-day survival with neurologic assessment. This registry has been described elsewhere.<sup>10</sup>

For our study, we included only witnessed non-traumatic OHCA in which resuscitation was attempted and for which the time of collapse was accurately determined.

### EMS organization in France

France has a two-tiered, physician-based, EMS system for responses to all medical emergencies. There are 101 regional dispatching centers (called SAMU; Service d'Aide Medical d'Urgences) to cover its 66 million citizens. Each dispatching center may be reached by calling a national emergency number, "15," and is responsible for dispatching to the scene a physician-staffed ambulance and/or a fire ambulance staffed by emergency medical

technicians (EMT). For OHCA, the programmed response includes a physician-staffed ambulance and a fire ambulance.<sup>10,12</sup> All physician staffed pre-hospital emergency teams follow international resuscitation guidelines. This fact, should make the results of this study of interest to all other systems using the same guidelines.

#### Data from RéAC registry

Data abstracted from the RéAC registry included time of collapse, time of start of basic life support (BLS) CPR, start of advanced cardiac life support (ACLS) CPR (defined by time that medical team take over management of patient), time of return of spontaneous circulation (ROSC) or time of termination of resuscitation maneuvers, and times of important events (call to the dispatch center, arrival of EMT and physician at the scene) according to the Utstein style. Each RéAC investigator (one for each Samu) was designated to prospectively assess cerebral function in the 30-day survival patients group. The RéAC investigators were able to contact patient, the family or general practitioner of these patients in order to evaluate cerebral function at 30 days. The data are reported in the RéAC secured database ([www.registreac.org](http://www.registreac.org)). Cerebral function was assessed by Cerebral Performance Categories (CPC) score, in which categories 1 and 2 indicates favorable cerebral function.<sup>13</sup> Several quality controls are performed in real time during data input to detect errors, inconsistencies or out-of-bound values. Offline tests are performed to detect other types of errors that require verification from the participating SAMU. A clinical research associate assesses randomly chosen records in order to identify other inconsistencies or errors that should be included in the automated tests (on- or off-line).

#### Ethical approval

The RéAC registry was approved by the French advisory committee on information processing in health research (CCTIRS) and

by the French National Data Protection Commission (CNIL, authorisation number 910946). This study was approved by the people protection committee (CPP) as a medical assessment registry without a requirement for patient consent.

#### Study outcomes

Our primary endpoint was 30-day survival without neurologic sequelae (defined by CPC = 1 or 2).

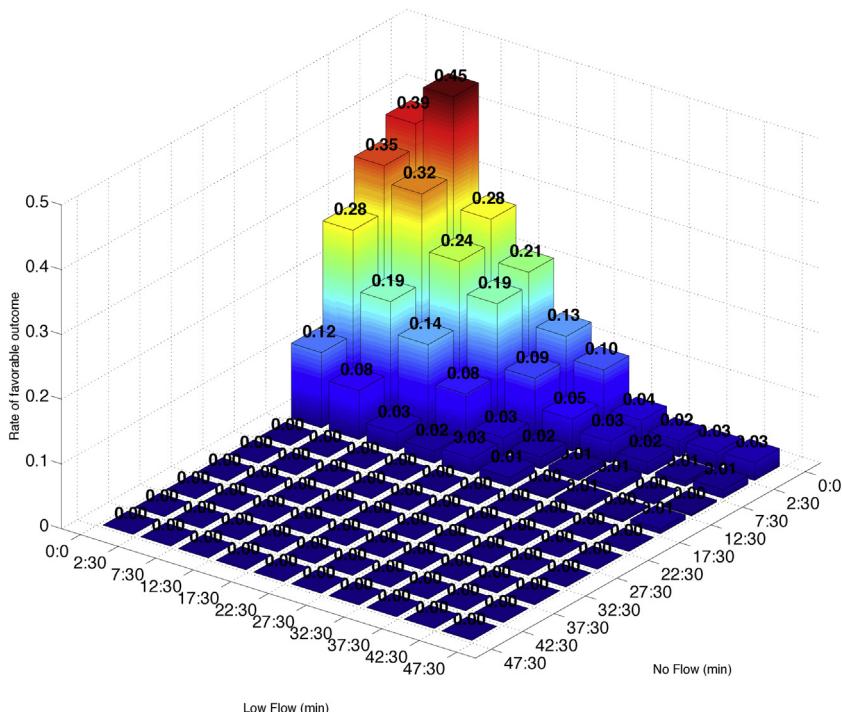
Cumulative incidence of ROSC and death with ending of CPR defines secondary outcome measures.

#### Statistical analysis

Data are reported as means ( $\pm$ SD) or medians (IQR) for continuous variables and as percentages for qualitative variables. Univariate associations were evaluated using the Wilcoxon rank sum test for quantitative data and the Chi-square test for qualitative data or the Fisher exact test, as appropriate.

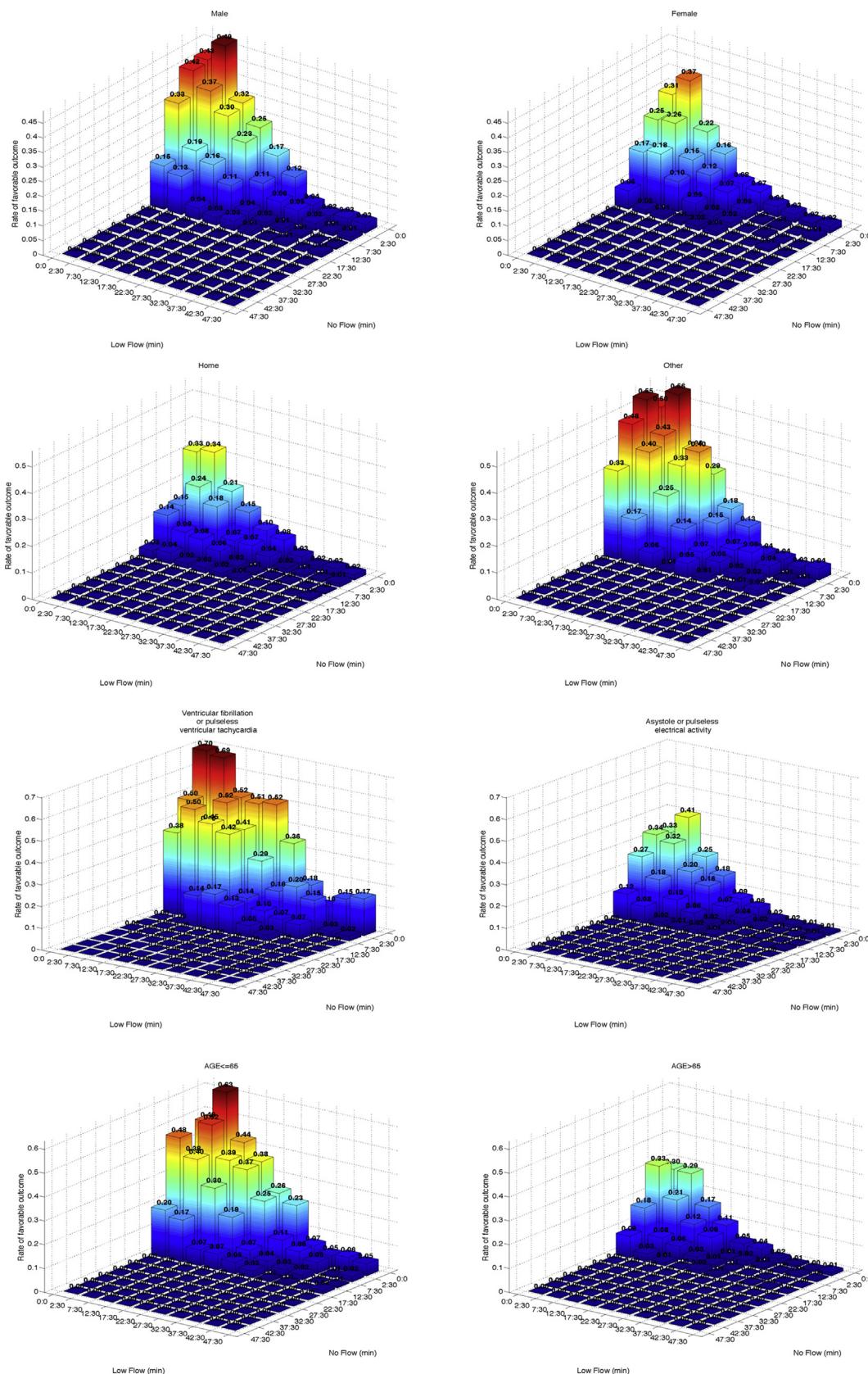
We wished to assess the influence of the durations of both NF and LF intervals on outcomes. However, these intervals are different from a statistical point of view. While the former is fully observed (though potentially with some inaccuracy), the latter is not observed in all the patients: actually, the decision of termination of resuscitation that yields to death precludes the occurrence of ROSC. Thus, for a patient for whom resuscitation has ended in death, one can only say that his (her) LF interval is higher than his (her) observation time; this defines right-censored data, so-called a failure time. Moreover, given the decision of discontinuation is likely dependent on the patient status, the censoring is not independent but informative of the underlying LF. Thus, such an informative mechanism has to be handled in the analysis to avoid bias in estimates. Therefore, two statistical approaches were used.

First, the 30-day survival without neurologic sequelae was treated as a binary outcome measure with nonparametric esti-



**Fig. 1.** Three-dimensional plot of the bivariate probabilities for survival with CPC 1-2 among all resuscitated patients as a function of no flow (NF) and low flow (LF). The height of each bar represents the observed probability of favorable outcomes as a function of NF and LF intervals (reported in each bar top).  
1A for the entire cohort (N=27,301).

2B: for subsets defined according to gender, age, initial cardiac rhythm and location of cardiac arrest.

**Fig. 1. (Continued)**

mates of those probabilities with 95% confidence intervals. Further adjustments for baseline predictors (sex, age, initial cardiac rhythm and location of cardiac arrest) were performed using multivariate

logistic regression models; odds ratios (OR) were computed as measures of association with the outcome. Contour lines as functions of

(NF, LF) values reaching similar estimated 30-day survival without neurologic sequelae (from 0.04 down to 0.01) were then plotted.

Second, we used a competing-risk framework to compute the cumulative incidence of ROSC, where death with ending of CPR defined the competing-risk outcome. Note that the existence of sequelae is unobservable at the time of ROSC, so that one cannot use the future (measure of CPC at day 30) in defining the outcome. Cumulative incidence of ROSC and death across NF levels was compared by the Gray test.<sup>14</sup>

Statistical analysis was performed using SAS (version 9.2; SAS Institute Inc., Cary, North Carolina) and R (<https://www.R-project.org/>) statistical software. All statistical tests were two-tailed with P values <0.05 considered significant.

## Results

### Study population

Between June 1, 2011, and December 1, 2015, we identified 40,098 OHCA. Among these patients, 33,907 were bystander-witnessed and time of collapse was known. We excluded 3472 cardiac arrests of traumatic etiology. Resuscitation was attempted in only 28,018 patients. Finally, information on outcome was incomplete or missing in 717 (2.6%); thus, these cases were excluded from the analysis. Among the 27,301 patients who had bystander-witnessed (or EMS-witnessed) out-of-hospital cardiac arrest from medical etiology and recorded data on both the start of CPR and survival, only 1,249 survived at 30 days post-arrest, with CPC score of 1 or 2 (4.57 percent; 95 percent confidence interval, 4.33 to 4.83 percent).

### Main outcome: 30-day survival without neurologic sequelae

The baseline characteristics and event characteristics in the RéAC cohort are summarized in Table 1.

Table 2 compares patient characteristics, OHCA characteristics, and duration of resuscitation between patients with favorable outcome (CPC 1 or 2) and others. As compared with patients with unfavorable outcome (CPC 3–4 or death), patients with CPC 1 or 2 were significantly younger, and their collapse was less likely to have occurred at home. This group also included fewer females, with a greater percentage of shockable rhythms as the first rhythm observed. NF (OR = 0.86 [per minute increase]; 95 percent confidence interval: 0.84–0.87) and LF (OR = 0.92 [per minute increase]; 95 percent confidence interval: 0.92–0.93) intervals were found to be inversely associated with a favorable outcome after OHCA ( $p < 0.001$ ). These effects of NF (adjusted OR = 0.89 [per minute increase]; 95 percent confidence interval: 0.88–0.91) and LF (OR = 0.93 [per minute increase]; 95 percent confidence interval: 0.93–0.94) persisted when adjusting for age, gender, cardiac rhythm and location of cardiac arrest.

We then determined how the values of NF and LF intervals act on the probability of 30-day survival without neurologic sequelae, using three-dimensional plots (Fig. 1A). One observes an exponential shape in survival rates as LF and NF intervals increase. Fig. 1B shows the influence of age, gender, initial cardiac rhythm and location of cardiac arrest on these plots. Expectedly, probability distributions were significantly ( $p < 0.001$ ) modified according to age (less or more than 65 years), sex, location of cardiac arrest or initial cardiac rhythm (Fig. 1B). Overall, the probabilities of 30-day survival without sequelae decreased dramatically when patients were older than 65 years, when cardiac arrest occurred at home and when initial rhythm was non-shockable.

Fig. 2A and B represents contour plots as a function of (NF, LF) values for similar estimated probability of 30-day survival without

neurologic sequelae, ranging from 0.16 down to 0.01. For the whole sample (Fig. 3A), a value of LF of greater than 30 min (95 percent confidence interval: 29–45 min), in association with a value of NF of less than 12 min (95 percent confidence interval: 11–13 min), was associated with a lower than 0.01 probability of 30-day survival without neurologic sequelae. Fig. 2B represents the influence of baseline characteristics on these curves. For example, if an OHCA patient has an initial shockable rhythm, the 30-day survival without neurologic sequelae of less than 0.01 is not reached until after 40 min of LF, given a NF interval less than 18 min. Inversely, when OHCA patients are found with non-shockable rhythm, CPR duration higher than 10 min is associated with poor outcome, whatever the duration of no flow. For males, less than 0.01 probability of 30-day survival without neurologic sequelae is observed when the area is defined by the values (NF, LF) above ( $NF_0 = 13$  min;  $LF_0 = 35$  min). A comparison of a 0.01 30-day survival without neurologic sequelae between those older than 65 years versus those younger than 65 reveals a much smaller area of NF; LF for the former.

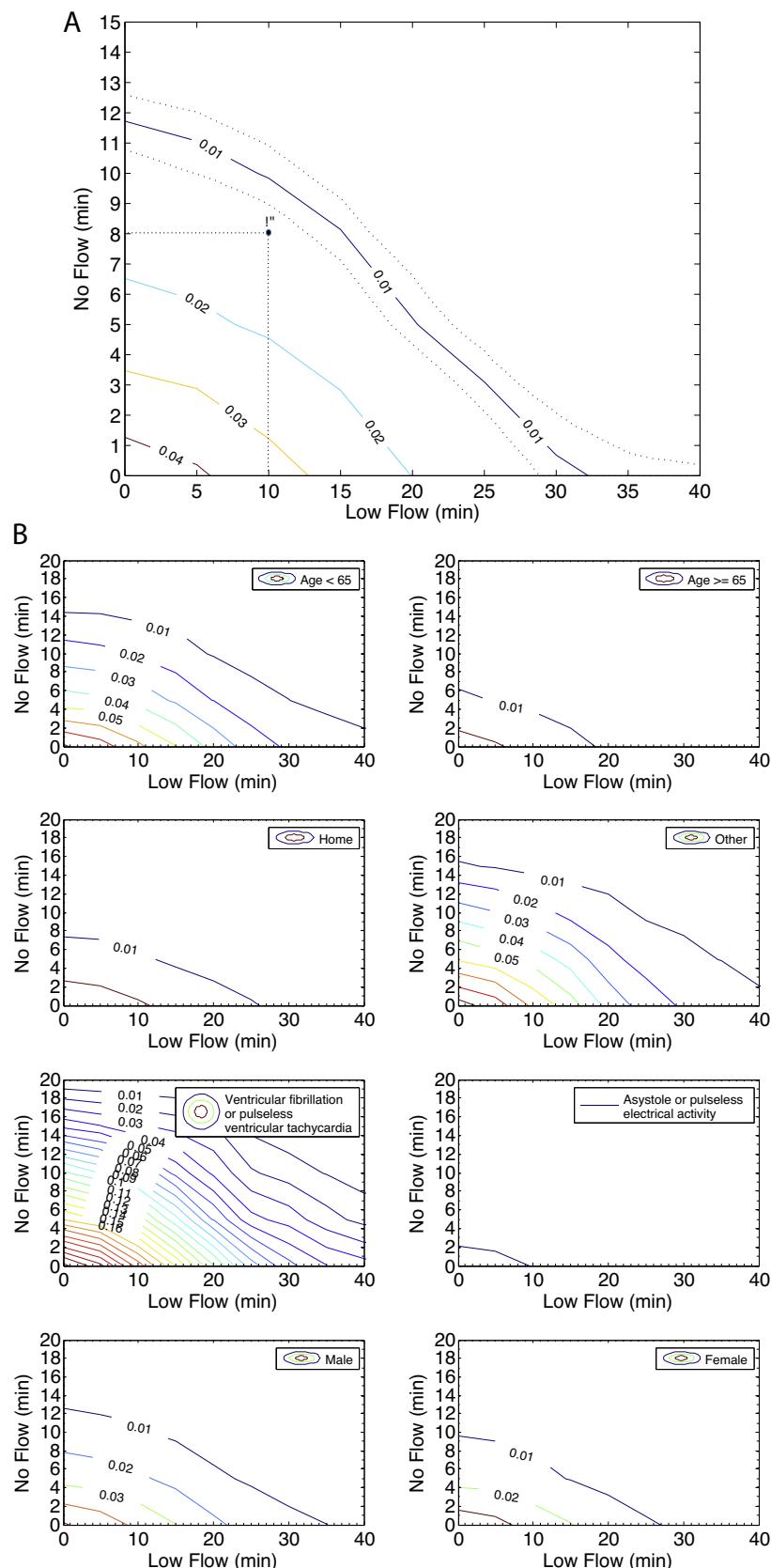
### Secondary outcomes: cumulative incidence of death and ROSC

Fig. 3A and B displays the cumulative incidence of ROSC and death according to the NF interval, respectively. When considered the whole population ( $N = 27,301$ ) we found the incidence of ROSC increased as the LF increases from a 2.7% estimated rate at 10 min up to 8.8% at 60 min. Moreover, when we stratified according to the NF interval (Fig. 3A), we found that the NF intervals is highly influential on the hazard of ROSC as the LF time increases ( $p < 0.001$ ), though erased for patients with NF over 35 min. In Fig. 3B we observe the same significative effect regarding relative cumulative incidence of death.

## Discussion

In the current study, we found a strong dependence between the no flow and low flow intervals (NF, LF) and the outcomes after out of hospital cardiac arrest.

We first considered the 30-day survival status of patients, without neurologic sequelae. Based on that outcome, we showed a significant inter-dependence between NF and LF: the relationship between LF and survival appears greatly influenced by the duration of estimated NF (Fig. 1A and B). Indeed, the interval of cardiac arrest (defined by NF plus LF) associated with highly functional (CPC 1 or 2) survivability above 0.01 seems to be impacted most by the value of NF (Fig. 2A and B). The shape of these curves was influenced by the widely recognized predictors of survival that were also confirmed in our study, namely the nature of the initial rhythm, location of cardiac arrest or advanced age of patients (Fig. 2B). For example, our results showed that a long interval of CPR (LF) is more often effective in the case of a shockable rhythm whatever the value of NF (Fig. 2B). This fact may be partially explained (1) by cardiac hemodynamics during ventricular fibrillation, where blood flow exponentially falls but continues for approximately 5 min without CPR and/or (2) by the time of collapse of the patient which, in fact, corresponds to a rhythm disorder that keeps transient hemodynamic efficiency.<sup>15</sup> Conversely, CPR exceeding 10 min in the case of a non-shockable initial rhythm, even in the case of EMS witnessed cardiac arrest (associated with NF = 0) appears to be associated with very poor outcomes (Fig. 2B). A recent study performed in 1617 OHCA patients found that probability of survival without sequelae fell below 1% with LF of 48 min in initial shockable rhythm and 15 min in the case of non-shockable rhythm.<sup>4</sup> In this study, authors did not take into account NF values. Current guidelines recommend that healthcare professionals consider empirically withholding or terminating CPR when asystole persists



**Fig. 2.** Contour lines as a function of no flow (NF) and low flow (LF) values for similar estimated probability of 30-day survival without neurologic sequelae as reported on the lines.

2A: for the entire cohort ( $N = 27,301$ ) with 95% confidence interval for 0.01 probability of day survival without neurologic sequelae. For a patient symbolized by the point A ( $LF_A = 10$  min;  $NF_A = 8$  min), the probability of survival without sequelae is comprise between 2% and 1%.

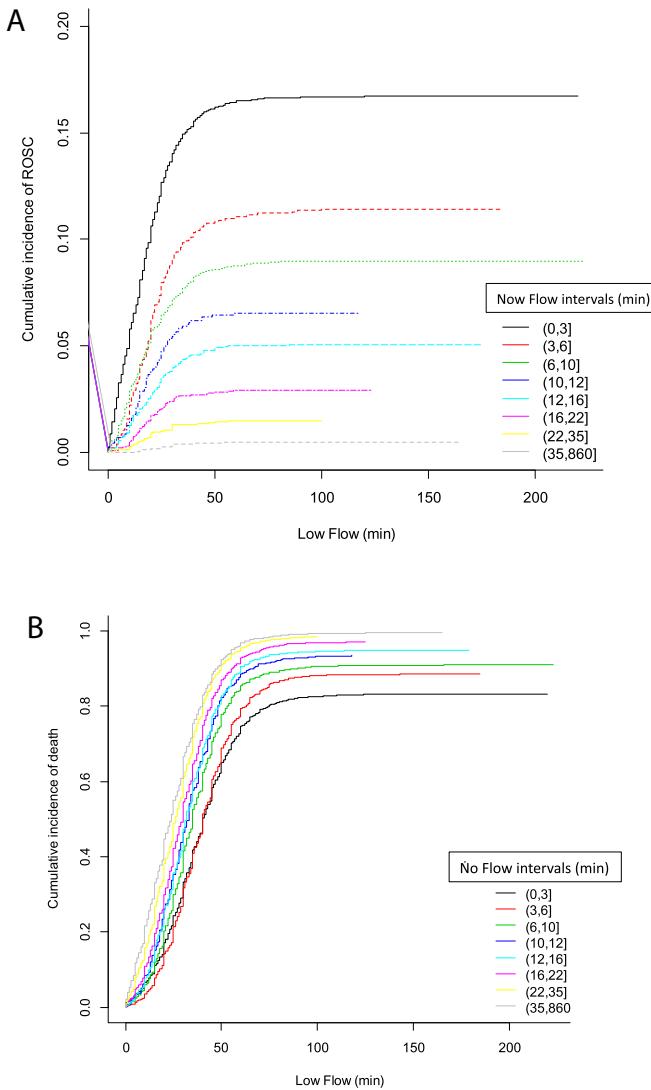
2B: for subsets defined according to gender, age, initial cardiac rhythm and location of cardiac arrest. For example, when initial rhythm was ventricular fibrillation; estimated probability of 30-day survival without neurologic sequelae was less than 1% for LF more than 40 min and NF more than 19 min. If initial rhythm was asystole these values become 10 min of low flow and 2 min of no flow.

**Table 2**

Rate of 30-day survival without sequelae in relation to main predictors.

Variable	CPC 3–5 (N = 26,052)	CPC 1–2 (N = 1249)	p
Age—median (10th–90th percentile)—year	71 (59–82)	58 (47–69)	<0.001
Age ≥65 year—(%)	16,096 (61.8)	394 (31.6)	<0.001
Male gender—(%)	16,824 (64.6)	904 (72.4)	<0.001
Collapse at home—(%)	19,416 (74.5)	561 (44.9)	<0.001
Shockable rhythm as initial ECG rhythm—(%)	2845 (10.9)	969 (77.6)	<0.001
Time intervals—median (10th–90th percentile)—min			
Collapse to start of CPR (no flow)	10 (2–17)	1 (0–5)	<0.001
Start of CPR to return of spontaneous circulation or termination of resuscitation (low flow)	31 (20–44)	13 (5–20)	<0.001

CPC denotes Cerebral Performance Categories; ECG denotes electrocardiogram; CPR denotes cardiopulmonary resuscitation.



**Fig. 3.** Estimated cumulative incidence curves of both ROSC (return of spontaneous circulation) and death following termination of cardiac resuscitation according to the NF intervals for the entire cohort (N = 27,301).

3A: cumulative incidence of ROSC according to the NF intervals.  
3B: cumulative incidence of death according to the NF intervals.

for more than 20 min despite ongoing CPR, in the absence of a reversible cause.<sup>16</sup> Our results provide strong evidence for these recommendations. Finally, we speculate that the knowledge of the characteristic intervals of (NF, LF) associated with poor outcome, defined by survival of less than 1 percent may be extremely helpful to a physician contemplating more aggressive interventions, such as extracorporeal cardiopulmonary resuscitation (ECPR) to

provide both mechanical circulatory support and gas exchange. On the other hand, these same curves may assist the physician to declare resuscitation futile and the patient dead and to consider the non-heart-beating donor orientation strategy, with the potential to increase the pool of solid organs available for transplant from non-survivors.

However, the relationship between duration of CPR and survival seems to be very complex. Notably, it is obvious that assessing the impact of LF on survival is complicated by the fact that LF may end with the physician's decision of stopping resuscitation, so that the value of LF interval defines a so-called "informative" right-censored endpoint. We thus used competing-risk methods for estimating the cumulative incidence of ROSC over the LF time, overall or according to the NF interval. We confirmed that the higher the NF, the lower the cumulative incidence of ROSC and the higher that of death, and that regardless of the LF interval (Fig. 3). Nevertheless, given a NF interval, the cumulative incidence of ROSC increased over the LF—though such an increase disappears for the highest values of NF (>35 min). Only a well-designed randomized clinical trial comparing "extended" CPR duration vs. "limited" CPR duration, if ethically acceptable, could definitively close the debate.

Other authors have found that longer duration of resuscitation may be associated with good outcomes.<sup>5</sup> In a large observational study of patients with intra-hospital cardiac arrest, hospitals with the longest resuscitation attempts (defined by NF + LF exceeding 25 min) had a higher risk-adjusted rate of ROSC and survival to discharge, compared to resuscitation attempts with a shorter median interval.<sup>5</sup> Another study found that where institutionally-imposed duration of CPR was greater than 30 min, the survival to discharge rate was significantly increased.<sup>3</sup> Conversely, other authors have found that the decision to employ novel therapies should be made early after cardiac arrest because of poor prognosis after only 16.1 min of CPR.<sup>17</sup> Most of these studies only considered one time interval of interest, ignoring the relationships between both NF and LF intervals, on which we focused in this work.

One of the greatest challenges facing clinicians is the decision of when to stop resuscitation efforts in patients in cardiac arrest. Some clinicians are reluctant to continue efforts when ROSC does not occur shortly after initiation of resuscitation, in view of the overall poor prognosis for such patients. Many investigators have tried to identify a factor associated with futile CPR (usually defined by survival less than 1 percent).<sup>18</sup> Our curves illustrated the logistic modeling results, that is, age, location of cardiac arrest, initial rhythm and sex are strongly associated with the outcome (Figs. 1B and 2B). We took advantage of the contour plots (Fig. 2) to display the pairs of (NF, LF) values associated with similar outcome estimates, overall and for each prognostic subset.

These contour plots could be helpful as decision-tools to identify an optimal transition time to ECPR in case of predicted "good" neurological outcome in patients with OHCA. Indeed, ECPR is a novel strategy for refractory cardiac arrest, that employs a modified form of cardiopulmonary bypass, maintaining circulation until

an effective cardiac output can be restored. This new technique is associated with low-quality evidence suggesting a benefit in regard to survival and favorable neurologic outcome, when compared with conventional CPR in OHCA patients.<sup>9,19</sup> A recent meta-analysis showed the benefit in survival of this technique among patients specifically with cardiac origin out-of hospital and in-hospital cardiac arrest patients.<sup>20</sup> A few authors have recommended the initiation of ECPR in patients in whom more than 30 min of LF and less than 5 min of NF have failed to obtain a ROSC.<sup>21</sup> Others have suggested that ECPR should be considered in OHCA patients with more than 21 min of refractory CPR.<sup>22</sup> Choosing the optimal interval of traditional CPR after which to switch to an alternate approach requires an estimation of the probability of survival as a function of the duration of the resuscitative efforts. Our results indicate that the time to start these alternative techniques is very dependent on initial rhythm, age, and location of cardiac arrest, as well. In the case of a shockable rhythm, 21 min of LF was associated with an 11% survival without sequelae (Fig. 2B). This percentage must be taken into account to assess the benefits of new resuscitation techniques.

Our study has some limitations. Our data emanated from a national registry (RéAC), rather than a single EMS unit, inevitably introducing some variability in treatment approaches. However, to date, it includes approximately 70% of OHCA occurring in France, thus representing a broad swath of the country. Due to the emergency setting, most of variables were recorded on the basis of personal interview, in particular no-flow and low flow. Other variables were digitally registered. Survival after OHCA may be influenced by novel therapy in intensive care, but it is clear that the main novel therapy in intensive care (i.e. hypothermia) remains very controversial.<sup>23,24</sup> Our study was conducted in France with a prehospital medical system different from paramedic-based systems often found in other countries. This fact may preclude generalizing the findings to other emergency medical systems. Nonetheless, our results appear very coherent with current international (both European and American) guidelines for resuscitation.

## Conclusion

In conclusion, our study showed that the no flow interval must be considered in order to determine the duration of CPR in out-of-hospital cardiac arrest. The contour plots of survival probabilities as functions of (NF, LF) interval values according to age, initial rhythm, location of cardiac arrest or gender may aid in the decision process for cessation of CPR or consideration of alternative techniques.

## Conflict of interest statement

No conflicts of interest.

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