

Digit Preference and Biased Conclusions in Cardiac Arrest Studies

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Abstract

Introduction

In cardiac arrest (CA), time is directly predictive of patient prognosis. The increase in mortality resulting from delayed cardiopulmonary resuscitation has been quantified minute by minute. Times reported in such a situation could reflect a bias referred to as “digit preference”. This phenomenon leads to privilege certain numerical values (like 2, 5, or 10) over others (like 13). We investigated this bias in times reported during cardiac arrest management in a national register.

Methods

We analyzed data from the French National Electronic Registry of Cardiac Arrests. All the data, including the twelve times corresponding to the main steps of the management of cardiac arrest are prospectively reported by the emergency physician who managed the patients in prehospital settings. The frequency of times as multiples of 15 (0, 15, 30, and 45) was our primary end-point.

Results

47,211 times related to 6,131 cardiac arrests were analyzed. The most overrepresented numbers were: 0, with 3,737 occurrences (8% vs 2% expected, $p < 0,0001$) and 30, with 2,807 occurrences (6% vs 2% expected, $p < 0,0001$). Times as multiples of 5 and 10 were overrepresented (52% vs 20% and 10% expected, $p < 0,0001$).

Conclusion

Prospectively collected time were considerably influenced by digit preference phenomenon. Studies that are not based on automatic recording of times as well as studies that have not evaluated and considered this bias should be interpreted with caution.

Introduction

Time is of the essence in emergencies. In the context of cardiac arrests, time is directly predictive of patient prognosis. Numerous studies have established a correlation between the delay in the initiation of cardio-pulmonary resuscitation (CPR), specifically external chest compressions and defibrillation, and patient prognosis.[1–3] The increase in mortality resulting from delayed CPR has been quantified minute by minute. These correlations emerged from observational studies.[1–3] However, it is well established that data obtained from this type of study, taken and recorded by individuals, can be imbued with uncertainty. One of the uncertainties we should keep in mind when reading these observational studies is called “digit preference”. This phenomenon can lead us to privilege certain numerical values over others. [4] It has been shown, for example, that values such as 2, 5, or 10 were over-represented while others, like 13 - supposedly unlucky - tend to be underrepresented.[5] This phenomenon has been previously described in medical practice, particularly in blood pressure measurement.[6, 7] In the field of emergency

medicine, it has been reported in a study on the amount of time patients spent in an emergency department.[8]

We must therefore be cautious when interpreting results of studies that demonstrate a strong tendency toward digit preference. This can be particularly problematic when time is crucial to determining prognosis and/or when it dictates therapeutic options. We explored the question of what proportion of values reported in emergency settings, particularly as they relate to cardiac arrest, are subject to the digit preference phenomenon.

Objectives

To identify digit preference-type phenomena in emergency department cardiac arrest record sheets.

Methods

Organization: In France, critical patients, including cardiac arrest patients, are managed in pre-hospital settings by specialized medical teams. France has approximately one hundred SAMU (Service d'Aide Médicale Urgente) centers across the country. These call centers are responsible for triaging emergency calls (Emergency Medical System, EMS) as well as for the dispatch of approximately 500 mobile intensive care units (MICU).[9] These teams, which include an emergency physician, are responsible for the prehospital management of cardiac arrest patients.

We analyzed the prospective data from RéAC, the French National Electronic Registry of Cardiac Arrests which compiles information on prehospital management of cardiac arrests in France. The detailed methodology involved in the creation of this registry has previously been published.[10] Since its inception in 2011, patient data has been added to this registry by the attending physician on board the responding MICU. All the data are reported by the physician in a dedicated case report form. Local investigators (one per MICU) and a primary investigator (JMA, PN, LM JM) record the data in the national register and ensure the comprehensiveness and the quality of the data.

Site: Our department, Seine-Saint-Denis, is situated on the border of north-eastern Paris. It is a completely urbanized area of 256 km² with a population of 1.6 million. Five MICUs ensure prehospital care for critical patients.

Inclusion Criteria: All patients managed by a mobile intensive care unit and presenting with cardiac arrest, whether or not resuscitative measures were undertaken by the medical team, are prospectively included in the registry.

Exclusion Criteria: No patients were excluded from the registry.

Selected Parameters: Demographic data, medical history and cardiovascular risk factors, caller information, description of the circumstances during which the cardiac arrest occurred and information on prehospital care including the use of a defibrillator, resuscitative measures undertaken by bystanders,

as well as patient destination and outcome. All times noted on the record sheets pertaining to patient care were counted in their entirety and corresponded to the following events: time of cardiac arrest (estimated by family or witnesses); time at which witnesses called the SAMU-EMS (automatically registered in the patient file but not in the register case report form); time at which resuscitative measures, if any, were undertaken by witnesses; first responders' arrival time; time of the emergency medical team's departure from the local hospital and arrival at the scene; time at which the defibrillator was used; time at which the first external electric shock occurred, if any; time of return of spontaneous circulation for over one minute, if applicable; time at which resuscitative measures were terminated; and finally, departure time from the scene and arrival time at the hospital (accounted for by the physician in charge of the patient's care). The delays were then automatically calculated from the given times.

Our analysis was focused on these twelve times. Our hypothesis was that the times transcribed are subject to digit preference phenomenon, and that this phenomenon had a more marked effect when the times in question were estimated (for example, the time at which a cardiac arrest occurred) than when these times can be precisely noted (arrival time at the scene) or automatically recorded (time at which a witness called the SAMU-EMS).

End-points: The frequency of times as multiples of 15 (0, 15, 30, and 45) was selected as our primary end-point. The frequency of times as multiples of 10 (0, 10, 20, 30, 40, and 50) and multiples of 5 (0, 5, 10, 15, 20, 25, 30, 35, 40, 45, 50, and 55) were selected as secondary end-points. We also wanted to determine if certain numbers which carry a particular symbolic value (7, 13) were preferred or avoided.

Ethical and Regulatory Framework: Data, including relevant times, are collected prospectively and reported in the RéAC register case report forms (CRFs) by the emergency physician. This register was approved by the French Advisory Committee on Information Processing in Material Research in the Field of Health (CCTIRS) and by the French National Commission on Informatics and Liberty (CNIL, France's data protection bureau - 910946). RéAC was approved as a professional practices register which may operate without patient consent.[10] Data collection practices were in accordance with the Declaration of Helsinki, and each patient was provided specific information. The CRFs were anonymized in accordance with CNIL guidelines.

Statistical Analysis: We presumed that the distribution of the times at which each cardiac event occurred must be random, and therefore, that the probability of occurrence was equal for each minute of each hour, resulting in a probability of 1/60th or 1.7%. We then compared this theoretical distribution with the actual distribution. This analysis was completed for the all twelve of the times cited above as a whole and then for three key times individually: the time (or estimated time) at which the cardiac event occurred, the time at which a witness placed the call to the SAMU-EMS (automatically recorded in the patient file), and the time at which the medical team arrived on the scene (accounted for by the physician). We used a Chi-squared test to analyze the data. We analyzed the minutes and their distribution, minute by minute, over an hour.

Results

Data concerning the 6,131 patients included in the register from 2011 to 2020 were analyzed. This included 3,852 (63%) men and 2,279 (37%) women. The median age was 67 (52–81) years. In total, 47,211 times were analyzed. Their distribution is presented by the terminal digit in Fig. 1 (the figures with the detail of the twelve studied times is available in annex 1). Zero was the most overrepresented digit, with 14,554 occurrences (31%, $p < 0,0001$), followed by 5, with 9,803 occurrences (21%, $p < 0,0001$). One was the most underrepresented digit, with 2,297 occurrences (5%, $p < 0,0001$), followed by 9, with 2,280 occurrences (5%, $p < 0,0001$).

The global distribution of the times, minute by minute over the course of an hour, is presented in Fig. 2 (the figures with the detail of the twelve studied times is available in annex 2). The most overrepresented numbers, in decreasing order, were: 0, with 3,737 occurrences (8%, $p < 0,0001$), 30, with 2,807 occurrences (6%, $p < 0,0001$), and 20, with 2,024 occurrences (4%, $p < 0,0001$). Times as multiples of 5 and 10 were overrepresented (52%, $p < 0,0001$) (Table 1). The values surrounding these peaks were always underrepresented. The most underrepresented values were 29, with 349 occurrences (1%, $p < 0,0001$), followed by 51, with 350 occurrences (1%, $p < 0,0001$).

For the 6,117 estimated times at which a cardiac arrest occurred, 0 was found in 1,529 occurrences (25%, $p < 0,0001$) and the number 30 in 781 occurrences (13%, $p < 0,0001$) (Fig. 2). Times as multiples of five were overrepresented, found in 4,898 occurrences, representing 80% of the recorded times ($p < 0,0001$) (Fig. 3 and Table 1).

For the 6,131 times at which the medical team arrived on the scene, recorded by the physician, the numbers 20, 10, and 0 were the most overrepresented: they accounted for 248 (4%, $p < 0,0001$), 234 (4%, $p < 0,0001$), and 228 (4%, $p < 0,0001$) occurrences respectively. Times as multiples of 5 were overrepresented, with 2,534 occurrences, representing 41% of the recorded times ($p < 0,0001$) (Fig. 4 and Table 1).

For the 6,131 times at which witnesses called the SAMU-EMS, which are automatically recorded, 0 was found in 312 occurrences (5%, $p < 0,0001$) and the number 30 was found in 275 occurrences (4%, $p < 0,0001$) (Fig. 4). Times as multiples of 5 were overrepresented, with 2,421 occurrences, representing 39% of recorded times ($p < 0,0001$) (Fig. 5 and Table 1).

Table 1
Comparative Occurrence of the Numbers 0, 30, and Multiples of 5, 10, and 15

Occurrence	Minute 0	Minute 30	Multiple of 5	Multiple of 10	Multiple of 15
Theoretical	2%	2%	20%	10%	7%
Global N = 47,211	N = 3,737 8%	N = 2,807 6%	N = 24,357 52%	N = 14,554 31%	N = 10,511 22%
p	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001
Time of CA N = 6,117	N = 1,529 25%	N = 781 13%	N = 4,898 80%	N = 3,542 58%	N = 2,983 49%
p	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001
Time of call to SAMU-EMS N = 6,131	N = 312 5%	N = 275 5%	N = 2,421 40%	N = 1,401 23%	N = 1,005 16%
p	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001
MICU arrival time N = 6,131	N = 228 4%	N = 222 4%	N = 2,534 41%	N = 1,337 22%	N = 883 14%
p	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001
CA: cardiac arrest					

Discussion

Prospectively collected time data from a national cardiac arrest register were considerably influenced by the digit preference phenomenon. This phenomenon was most marked when the times reported were estimated. The reported time of cardiac arrest fell “on the hour” in 25% of cases - as opposed to the expected 2%. Such a result demands that we approach studies based on the analysis of times at which a cardiac arrest was tended to with extreme caution. Studies that are not based on automatic recording of times, which are not subject to digit preference, and those that have not considered this bias (by looking for it, measuring it and correcting it) should be systematically omitted. Maintaining accurate registers is fundamental to both better understanding and improved treatment of cardiac arrest. Modern tools must allow us to avoid major biases such as this one in the collection of data.

We know that the primary determinant of patient prognosis after cardiac arrest is the time between cardiac arrest and the initiation of cardiopulmonary resuscitation, a delay also called no-flow. The second prognostic criterion is the time between cardiac arrest and defibrillation. In both cases, the time at which cardiac arrest occurred is the starting point, but is it also the most uncertain and most misreported time. In one of the first studies on defibrillation, the authors reported a decreasing prognosis minute by minute. The time at which cardiac arrest occurred was recorded, *"in the interview, an estimate was made of the time elapsed from the patient's collapse to receipt of the telephone call to 911"*.^[1] More recently, in an analysis on patient prognosis in which the elapsed time was broken down in two-minute intervals beginning with the moment cardiac arrest occurred, the information was collected by *"pre-coded sets of questions that ambulance staff are required to answer"*.^[2] In the multiple studies on cardiac arrest in which the chronological sequence of events starting with cardiac arrest were analyzed, we did not find an analysis of the distribution of time frequencies or of elements that allowed us to disregard a potential bias linked to the digit preference phenomenon. However, all studies on cardiac arrests are based on this starting point, the time at which cardiac arrest occurred, which we have strong reason to believe is more often than not recorded with significant bias. This bias should make us reconsider the relevance of many of these studies.

This is a well-known bias.^[11] It has been demonstrated in numerous scientific and medical fields and was particularly studied in reports of arterial blood pressure measurements.^[6, 7, 12] In a recent study, blood pressure values that ended in 0 were largely predominant, a phenomenon which is mirrored in our analysis.^[7] In emergency medicine, this bias was demonstrated in patient arrival and departure time records. Times which included a 0 were largely predominant. The negative organizational consequences of this bias have been highlighted.^[8] In order to eliminate this bias, the authors introduced an automated system to record the time.^[13] In the case of cardiac arrests, the time at which they occurred is based on an estimation out of necessity. The use of an automated system is not an option. In order to correct this bias, we must therefore base ourselves on the information received from the personnel who record this information. Consideration of this bias is crucial, not only for the scientific reasons mentioned above, but also because the length of "no-flow" time before the first resuscitative measures are attempted determines the medical team's decision to continue or stop such measures.^[14] Concerning the other key steps of resuscitation, we must put in maximal effort to ensure the automation of time records. Certain authors have also proposed statistical methods in order to detect and avoid this bias.^[12, 15, 16] Nevertheless, the bias reported here clearly occurs more frequently than other biases generally observed.^[12] It is unclear how the methods of correction which, to the best of our knowledge, have never been considered in studies on cardiac arrest, would allow us to avoid this bias.

Limitations

The main limitation of our study is the uncertainty of the consequences of such a major bias on the interpretation of previously published studies on cardiac arrest. To the best of our knowledge, papers on cardiac arrest are usually based on times reported by medical teams and therefore are subject to human error and can be suspected of this bias. However, an optimistic perspective could be that, in other

countries or, with other emergency care providers, digit preference phenomenon is less marked. There is no doubt that this has to be assessed.

Conclusion

Prospectively collected and nationally registered times pertaining to cardiac arrest were considerably influenced by a digit preference phenomenon, which leads us to the creation of major biases. The foundation of all studies on cardiac arrest, particularly the time of occurrence, is marred with a level of approximation which must make us cautious in our analysis of all studies pertaining to cardiac arrest. It is absolutely essential to explain how this bias is addressed in all studies on cardiac arrest.

List Of Abbreviations

CA: cardiac arrest

CCTIRS: Advisory Committee on Information Processing in Material Research in the Field of Health

CNIL: National Commission on Informatics and Liberty

CPR: cardio-pulmonary resuscitation

CRF: case report forms

EMS: Emergency Medical System

MICU: mobile intensive care units

RéAC: National Electronic Registry of Cardiac Arrests

SAMU: Service d'Aide Médicale Urgente

Declarations

- Ethics approval and consent to participate: also see the methods section

This register was approved by the French Advisory Committee on Information Processing in Material Research in the Field of Health (CCTIRS) and by the French National Commission on Informatics and Liberty (CNIL, France's data protection bureau - 910946).

- Consent for publication: not applicable
- Availability of data and materials: All data generated or analysed during this study are included in this published article
- Competing interests

Frédéric Lapostolle: Astra-Zeneca, Bayer, BMS, Boehringer-Ingelheim, Medtronic, Merck-Serono, Mundipharma, Novartis, Pfizer, Teleflex

Elodie Schneider, Jean-Marc Agostinucci, Pierre Nadiras, Laurence Martineau, Jacques Metzger, Philippe Bertrand, Tomislav Petrovic, Isabelle Vianu, Frédéric Adnet : none

- Funding: none
- Authors' contributions

Study conception and design: FL, FA

Acquisition of data: JMA, PN, LM, JM, PB

Analysis and interpretation of data: JMA, ES, FL

Drafting of manuscript: FL, TP

Critical revision: TP, IV, FA

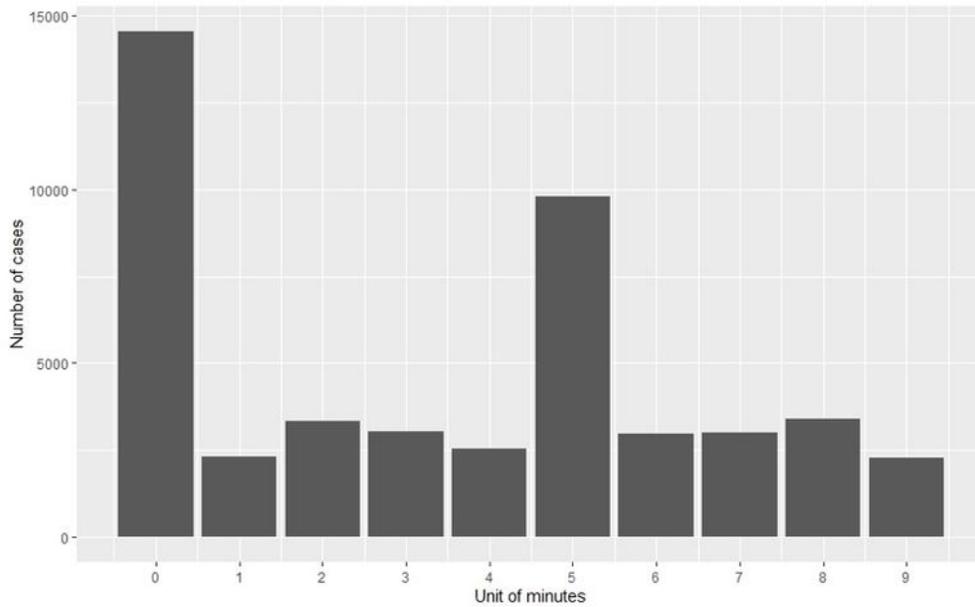
- Acknowledgements: none

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Figures



Annex - Figure 1:

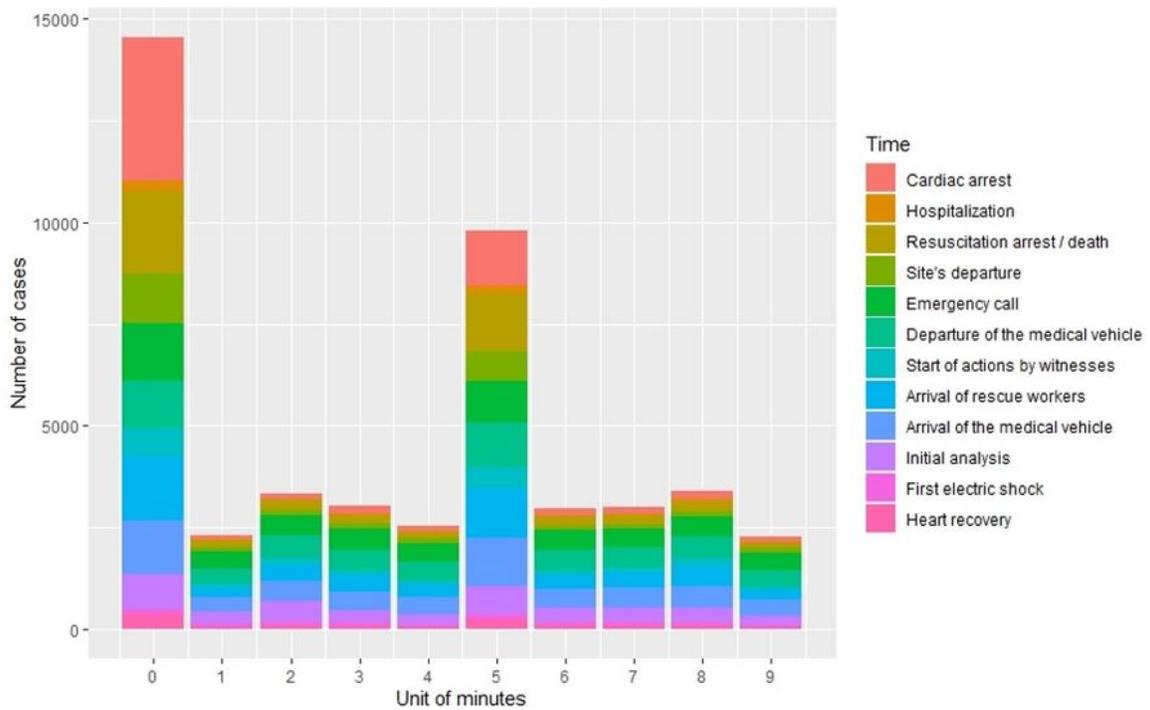
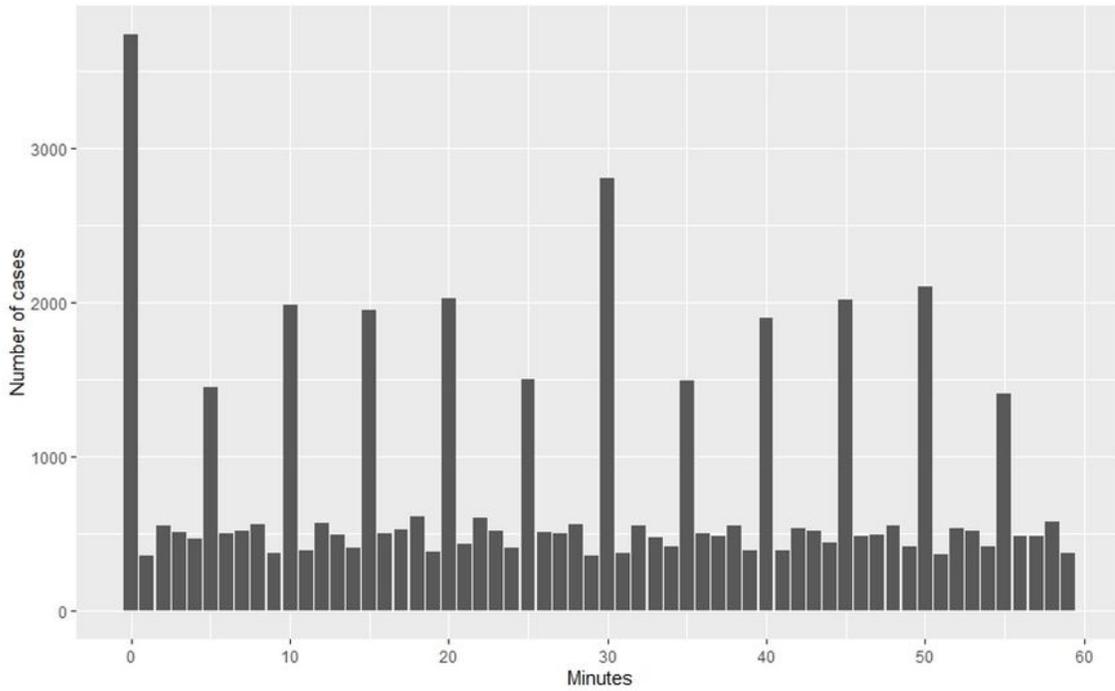


Figure 1

Global distribution the terminal digit of the reported times (n=47,211) Annex - Figure 1: Global distribution the terminal digit of the twelve studied times (n=47,211)



Annex - Figure 2:

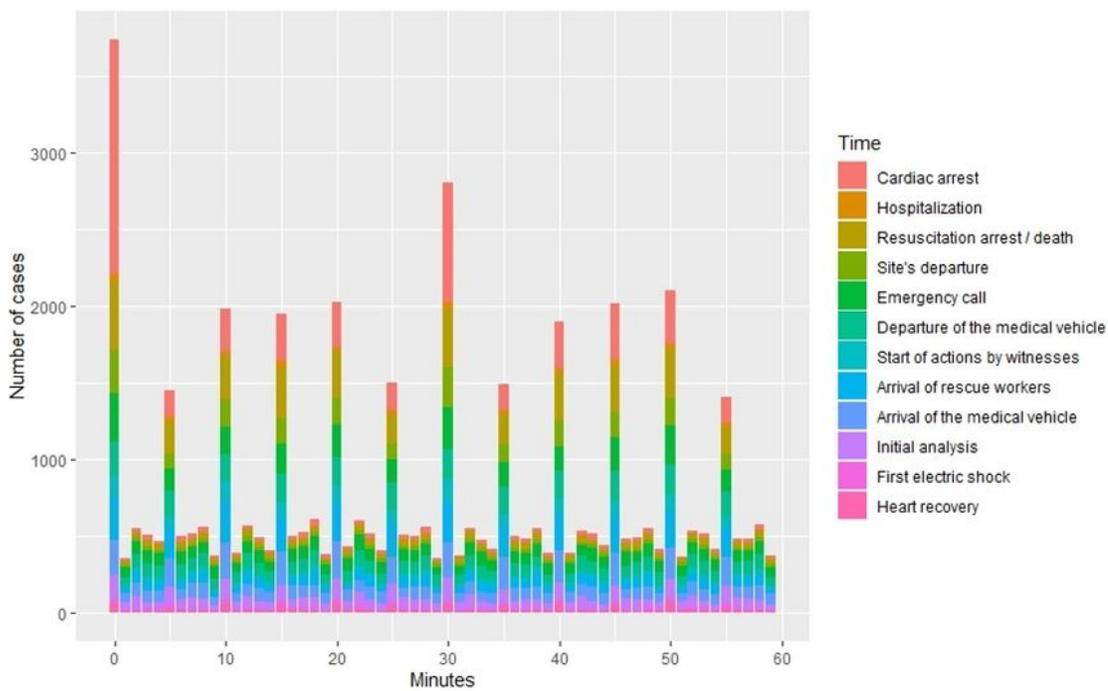


Figure 2

Time distribution minute by minute over the course of an hour (n=47,211) Annex - Figure 2: Time distribution minute by minute over the course of an hour of the twelve studied times (n=47,211)

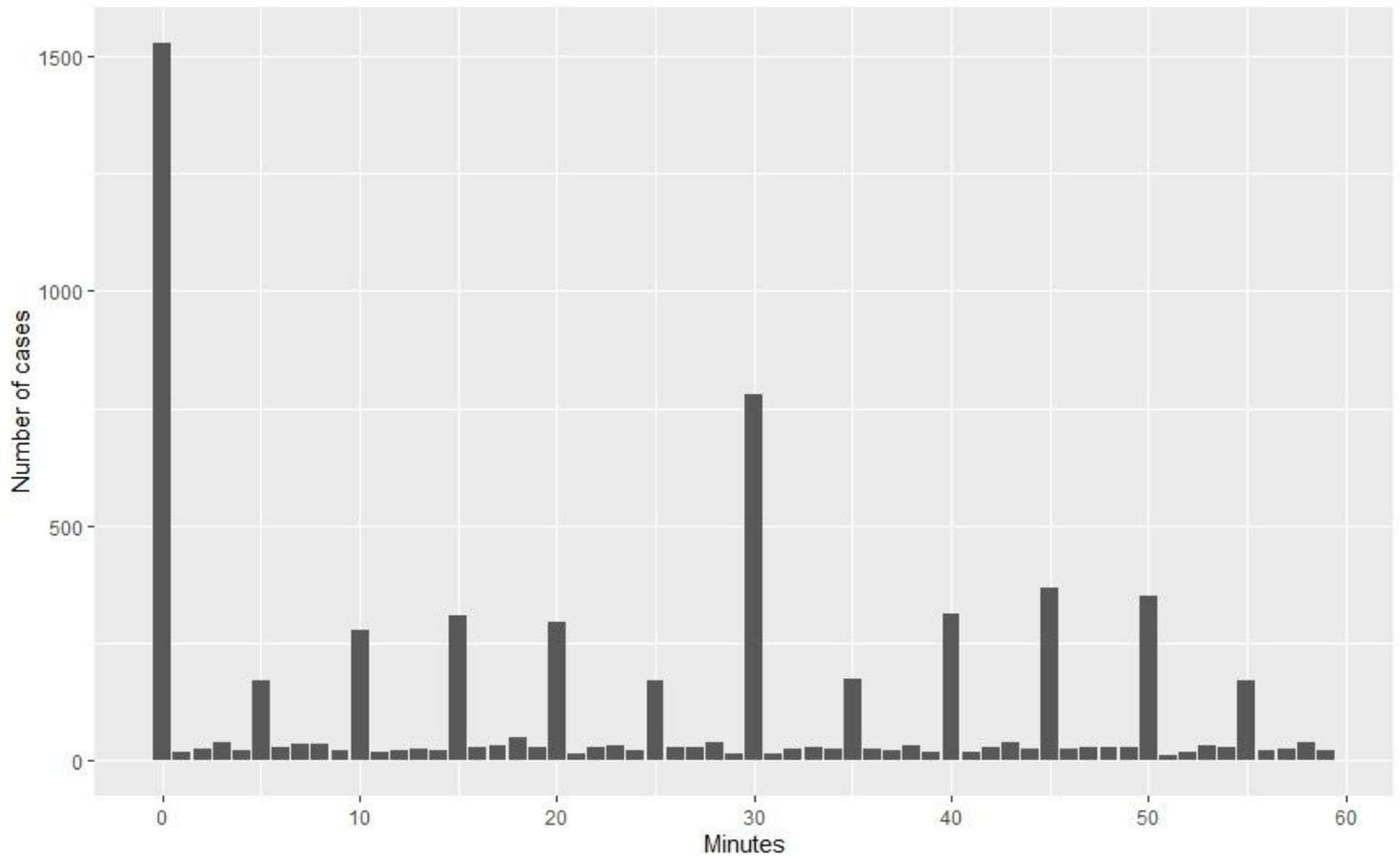


Figure 3

Distribution of the times at which a cardiac arrest occurred (N=6,117)

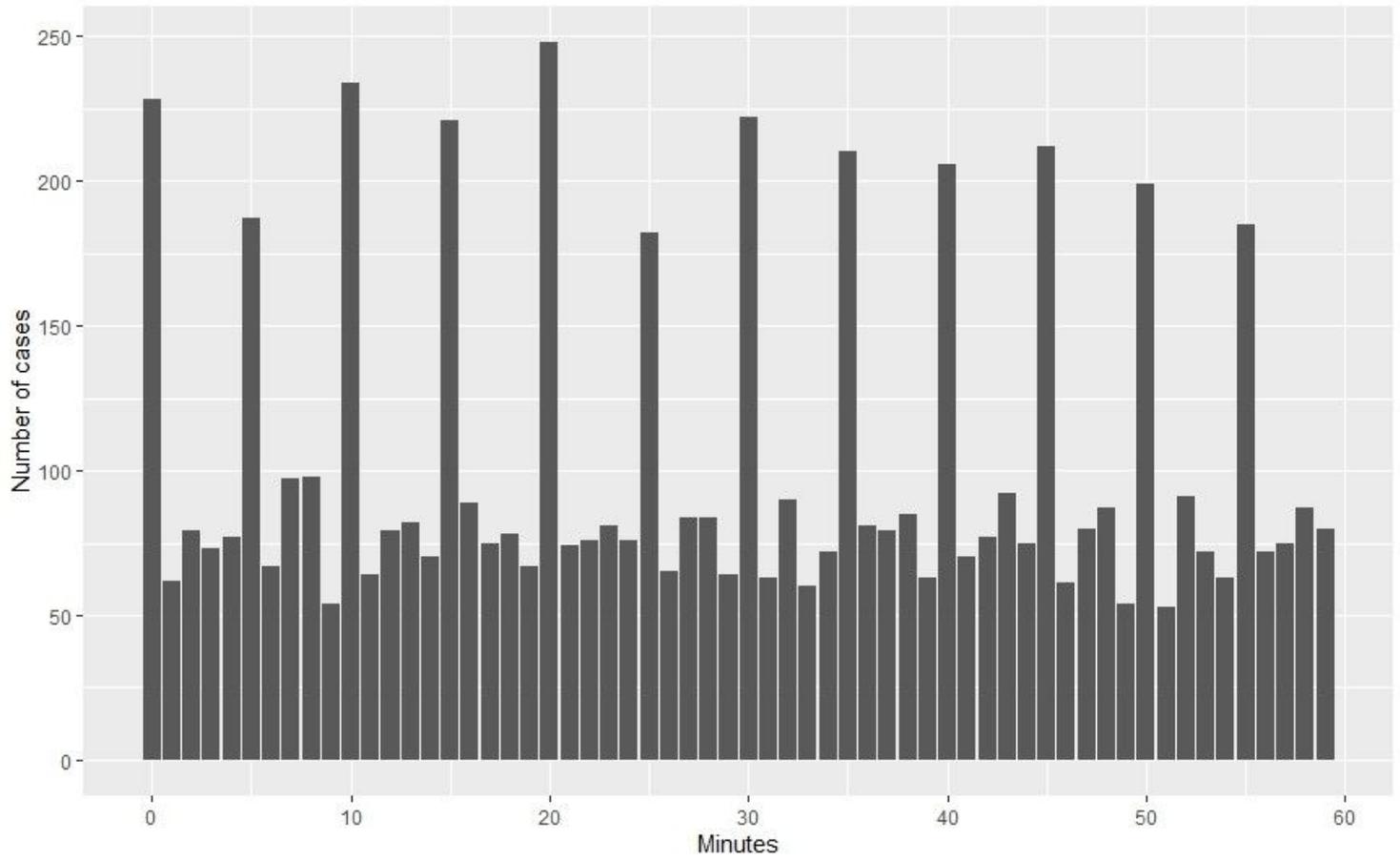


Figure 4

Distribution of measurable times of arrival by the MICU (N=6,131)

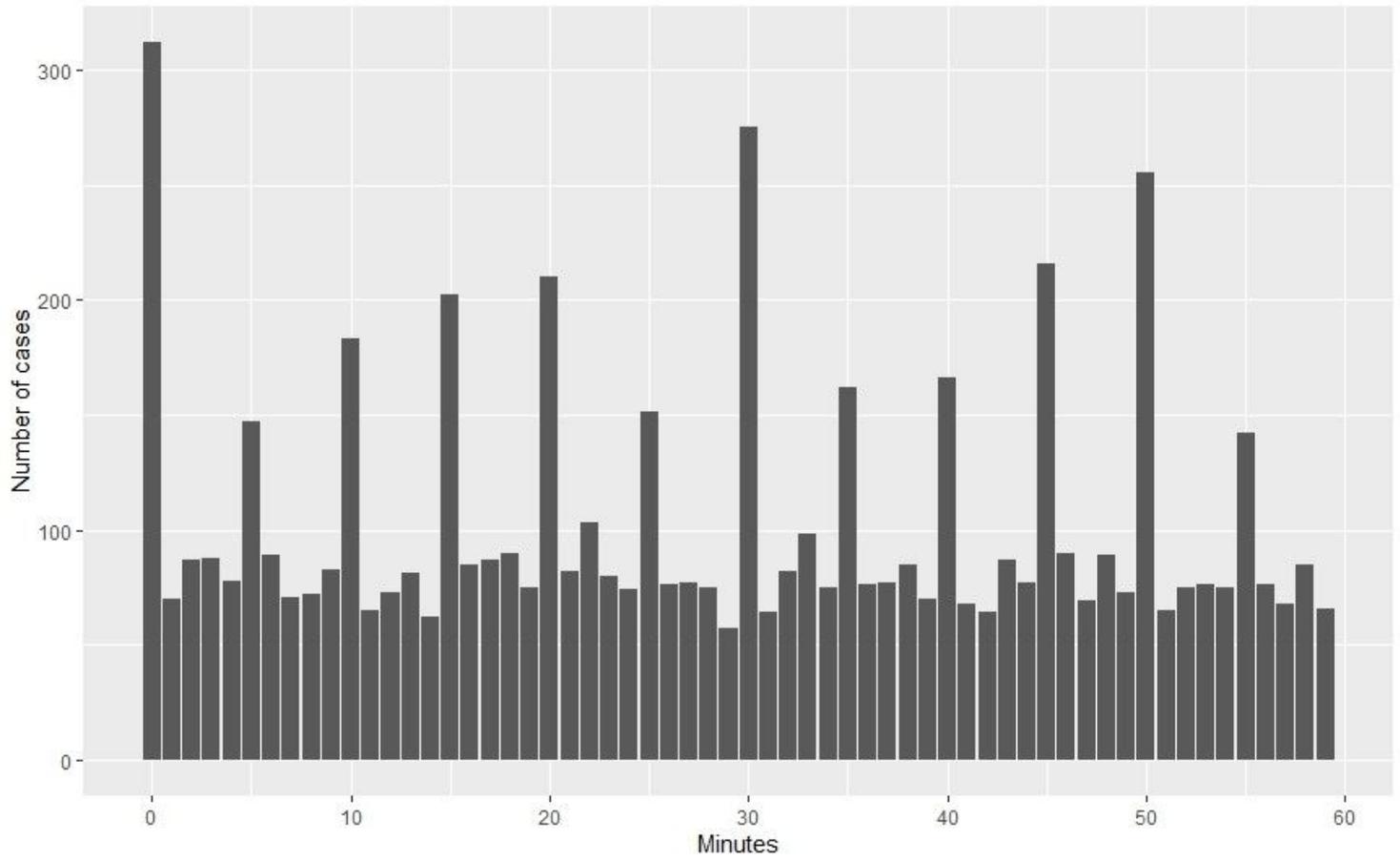


Figure 5

Recorded time of SAMU-EMS call (N=3,131)