

ORIGINAL ARTICLE

Out-of-hospital traumatic cardiac arrest: an underrecognized source of organ donors

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Conflict of interest

The authors declare that they have no conflict of interest.

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Introduction

The gap between organ supply and demand remains a worldwide concern. As the current shortage of organs for transplantation is increasing and the lists of recipients awaiting transplants are getting longer, all potential sources of organs must be explored [1]. During the last 10 years, many countries have been developing strategies

Summary

Whereas the gap between organ supply and demand remains a worldwide concern, resuscitation of out-of-hospital traumatic cardiac arrest (TCA) remains controversial. The aim of this study is to evaluate, in a prehospital medical care system, the number of organs transplanted from victims of out-of-hospital TCA. This is a descriptive study. Victims of TCA are collected in the out-of-hospital cardiac arrest registry of the French North Alpine Emergency Network from 2004 to 2008. In addition to the rates of admission and survival, brain-dead patients and the organ transplanted are described. Among the 540 resuscitated patients with suspected TCA, 79 were admitted to a hospital, 15 were discharged alive from the hospital, and 22 developed brain death. Nine of these became eventually organ donors, with 31 organs transplanted, all functional after 1 year. Out-of-hospital TCA should be resuscitated just as medical CA. With a steady prevalence in our network, 19% of admitted TCA survived to discharge, and 11% became organ donors. It is essential to raise awareness among rescue teams that out-of-hospital TCA are an organ source to consider seriously.

to increase the pool of potential donors, especially among victims of Cardiac Arrests (CA) [2]. In this context and with a poor personal prognosis, patients with resuscitated medical cardiac arrests that occur outside the hospital have been identified as potential good organ donors [3]. While performing cardiopulmonary resuscitation (CPR) for patients with medical CA is not controversial, the management of patients with traumatic CA (TCA)

outside the hospital remains challenging, leading some authors to consider resuscitation futile [4–6]. Most studies on this topic are based on data from North America, often carried out in urban systems without medical prehospital care. The National Association of EMS Physicians and the American College of Surgeons Committee on Trauma even recommend not resuscitating nonpenetrating trauma patients who do not have respiratory, circulatory, and organized electrical activity upon arrival on the scene [7].

The long-term survival of these patients is indeed poor, with an average survival rate of 5.6% (range 0–17%) [8].

In contrast, rates of return of spontaneous circulation (ROSC) and admission to the hospital alive are high (25% and 19%, respectively), and these patients are often younger and without prior disability [9].

Those patients that go on to develop brain death are potential organ donors [3]. A retrospective study by Schnüriger highlighted the benefits of aggressive hospital resuscitation of TCA patients to maximize organ donation [10].

The aim of this study is to evaluate, in a French regional prehospital medical care system, the number of organs transplanted from victims of out-of-hospital TCA.

Methods

Study setting

The study population comes from the out-of-hospital cardiac arrest registry of the North Alpine Emergency Network (Réseau Nord Alpin des Urgences, RENAU). All patients presenting with out-of-hospital CA cared for by a medical rescue team and receiving initial CPR were prospectively included in the register.

The RENAU includes medical facilities involved in the management of emergencies of three French departments: Isère, Savoie and Haute-Savoie, viz. a University Hospital (CHU) and nine General Hospitals (CHG). They operate according to the organization of French emergency care [11,12].

The area covered by the RENAU represents a population of 2 262 000 inhabitants over 17 847 km², a population density of 127 inhabitants/km² (vs. an average of 108 in France) [13]. It combines urban and rural areas, and mountain areas represent 51% of this region [14].

This network has been keeping a register of out-of-hospital CA since January 1, 2004, and gave us permission to use these data. This register has been declared to the National Commission on Information Technology and Freedom (Commission Nationale de l'Informatique et des Libertés, CNIL) and the Regional Ethics Committee.

The collection of data on the register is based on the Utstein Style [15]. Physicians who take care of CA patients

enter data prospectively. A clinical research associate and a referral physician then check the data and enter it into a central database. Information on the outcome of hospitalized patients is collected by contacting the receiving hospital departments. The completeness of the register is estimated at 81%.

Data on patients with brain death and on organ transplantation are collected from the receiving hospital departments, the prospective registries of organ donors maintained by hospital Committees on Organ and Tissue Donors, and the “Agence de Biomédecine” (national public reference organization on medical, ethical, and scientific aspects of organ donation) for national data [16].

The diagnosis of brain death (BD) is defined by French law on clinical criteria (lack of consciousness and of spontaneous motor activity, loss of all brainstem reflexes, and absence of spontaneous breathing) with the addition of either two flat electroencephalograms performed 4 h apart, or angiography (or CT-angiogram) demonstrating the absence of cerebral blood flow [17,18].

Four of the nine hospitals in RENAU have the capability to perform organ recovery. The only patients undergoing routine multi-organ recovery in France, at the date we are writing this article, are brain-dead patients. Over the duration of the study, there was no center performing donation after cardiac death (DCD) (controlled or uncontrolled) in our network: DCD was not allowed in France before 2006 and since then has been proposed in only ten volunteer pilot University Hospitals, after a long reflection among the National Academy of Medicine, the National Ethics Committee, and the French Agence de Biomédecine. The first such hospital in our area began performing DCD in 2011. Conversely, controlled DCD is still not allowed in France.

Criteria for inclusion and exclusion

Patients from the register were included if they were over 18 years of age, presented with traumatic out-of-hospital CA, and were admitted alive to a hospital between January 1, 2004, and December 31, 2008.

Cardiac arrest is defined by the absence of respiratory and cardiac activity in an unconscious patient. An EKG strip is systematically printed on the electrical defibrillator to confirm it.

The following data were recorded: age, sex, trauma mechanism, initial rhythm on medical rescue team arrival, ROSC, in-hospital outcome, number of organ donation procedures initiated, and number of organs transplanted.

The following were excluded from the study: (i) patients who had a CA of medical origin and secondary trauma due to the loss of consciousness, (ii) patients presenting with

severe trauma outside the hospital but whose CA intervened after arrival at the hospital, (iii) all CA of cardiac, hypoxic, and hemorrhagic (nontraumatic) etiology and CA due to drowning, electric shock, fire, and other non-traumatic etiologies.

Endpoints

The primary endpoint was the proportion of organs transplanted among out-of-hospital resuscitated TCA victims. Secondary endpoints were the TCA prevalence in the register, the types of injuries responsible, the number of patients discharged alive from the hospital, and the number of organ donation procedures initiated.

Statistical analysis

This study is purely descriptive: All criteria are expressed as numbers and percentages.

Results

From January 1, 2004 through December 31, 2008, 540 out-of-hospital traumatic CA underwent a resuscitation attempt.

Return of spontaneous circulation was achieved in 115 suspected TCA patients who were alive on arrival at the hospital (21.3%); 36 patients were excluded because the whole-body CT scan did not find any traumatic cause for

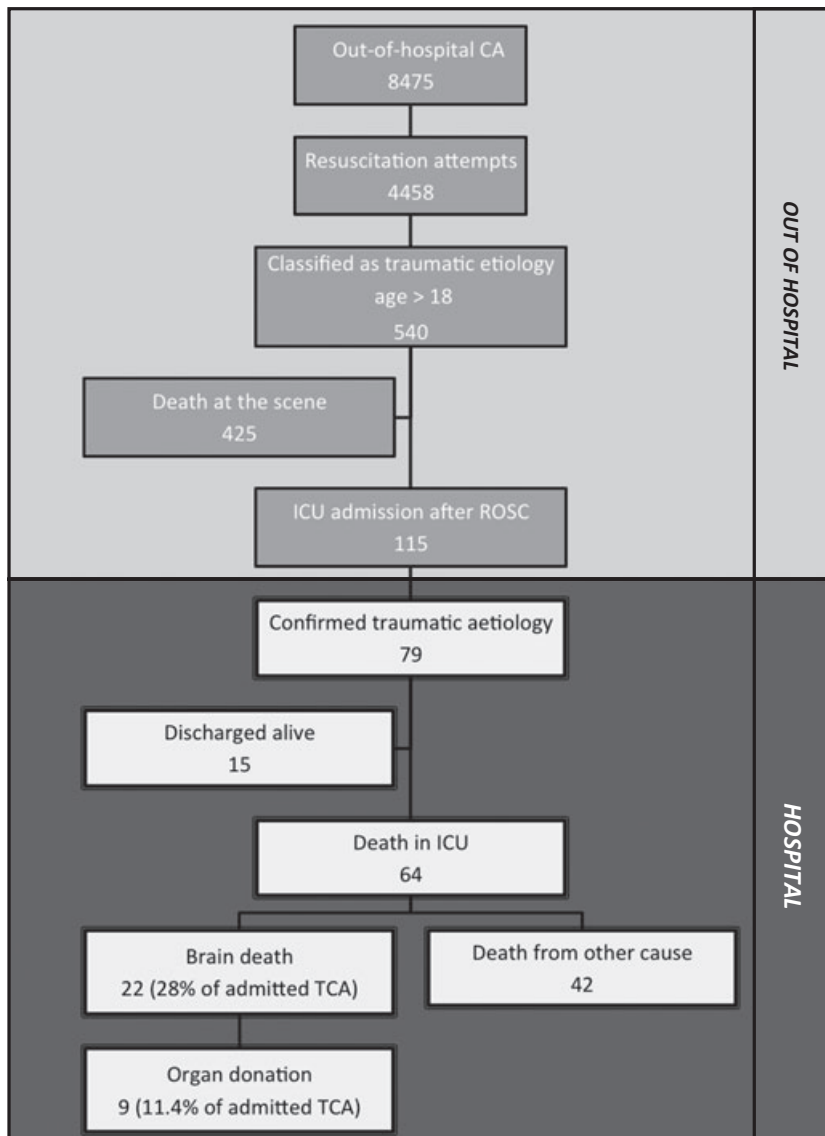


Figure 1 Out-of-hospital cardiac arrests, Réseau Nord Alpin des Urgences, data from 2004 to 2008. CA, Cardiac arrest; TCA, Traumatic cardiac arrest; ICU, Intensive care unit.

Table 1. Outcome of hospitalized patients according to the type of trauma.

	Survival (%)	Brain death (%)	Death from other causes (%)	Total
Blunt trauma				
Motor vehicle accident	6 (19)	7 (22)	19 (59)	32
Falls				
Mountain activity	3 (21)	5 (36)	6 (43)	14
Other falls	2 (12)	7 (44)	7 (44)	16
Other blunt trauma	2 (22)	2 (22)	5 (56)	9
Penetrating trauma	2 (29)	1 (14)	4 (57)	7
Unknown	0	0	1 (100)	1
Total	15 (19)	22 (28)	42 (53)	79

CA, Cardiac arrest.

the CA. Thus, 79 patients of 540 were admitted to the hospital following a confirmed traumatic out-of-hospital CA (15%) (Fig. 1).

During that period, 8475 patients with out-of-hospital CA of any etiology were identified by the RENA, and resuscitation was attempted on 4458 of these patients. This study analyses only the subset of traumatic CA among these.

The types of injuries are presented in Table 1. The leading causes are falls and motor vehicle accidents. In our geographic area, it seems relevant to separate patients who presented with a TCA during mountain activities (skiing,

mountaineering, paragliding), which represent 18% of hospitalized TCA.

The outcomes were as follows: (i) discharge alive from the hospital for 15 patients (19%), (ii) BD for 22 (27.8%) patients, and (iii) death from uncontrolled cardiac arrest (refractory shock, hemorrhage, multiple organ failure, etc.) for the 42 others. Only brain-dead patients were considered for organ donation.

Among the 22 potential organ donor BD patients, nine (41%) were eventually organ donors, leading to the recovery of 33 organs, namely four hearts, two lungs, six livers, 18 kidneys, and three pancreas (islets). 31 organs were grafted, without any organ dysfunction after 1 year. Data for these nine patients are shown in Table 2. For only one patient, the recovered organs could not be transplanted.

The reasons why organ donation was not performed for the other BD patients were two refusals expressed by the patients prior to the event, four refusals by relatives, four major hemodynamic instabilities, two medical contraindications, and one administrative issue (foreign patient).

Discussion

In our register and during the study period, the TCA prevalence was steady and represented 12% of all CA.

The first results indicate that 17% of TCA experienced a ROSC on the scene, almost 3% survived to hospital discharge and 4% evolved to BD. It appears that survival

Table 2. Epidemiological data for donor patients.

Patient number	Gender/ Age	Initial rhythm	No flow (min)	Low flow (min)	Lesions	Mechanism of trauma	Recovered organs	1-year survival of transplanted organs
1	M/43	Asystole	0	19	Isolated head trauma	Fall	Heart, liver, two kidneys, pancreas	100%
2	M/55	Asystole	18	27	Isolated head trauma	Motor Vehicle accident	Heart, liver, two kidneys	100%
3	M/19	Asystole	0	28	Head trauma, spine injury, severe thoracic injury	Motor Vehicle accident	Liver, two kidneys	100%
4	F/57	Asystole	17	44	Isolated head trauma	Fall	Two kidneys	Not transplanted
5	F/30	Asystole	0	20	Isolated head trauma	Fall in mountain setting	Heart, two lungs, liver, two kidneys, pancreas	100%
6	M/22	Asystole	0	5	Head trauma, nonhemorrhagic chest injury	Fall in mountain setting	Two kidneys	100%
7	M/49	Asystole	0	26	Isolated spine injury	Other	Two kidneys	100%
8	M/25	VF	12	45	Severe head trauma, nonhemorrhagic chest injury	Fall in mountain setting	Heart, two lungs, liver, two kidneys, pancreas	100%
9	M/38	Asystole	0	5	Isolated head trauma	Gunshot wound	Liver, two kidneys	100%

No Flow, time between cardiac arrest and initiation of cardiopulmonary resuscitation (CPR) (by witness or rescue team); Low Flow, time between initiation of CPR and resumption of spontaneous cardiac activity; VF, ventricular fibrillation.

after prehospital CA is possible and that TCA should receive resuscitation maneuvers. A Spanish study, with a medicalized prehospital system, included 167 TCA; an ROSC was obtained in 49% and a complete neurologic recovery in 6.6% of all patients [19]. In a British military study, conducted in Afghanistan over 8 months, the rates of ROSC on the scene and survival on discharge were similar [20]. In these two studies, the initial rhythm was asystole, as in our study, and the aggressiveness of resuscitation maneuvers on the scene was described as an important predictive factor of success. According to American guidelines, these patients should not be resuscitated. Current recommendations from North American scientific societies are not to resuscitate nonpenetrating trauma patients who present with no respiratory, circulatory, and organized cardiac electrical activity at the time the rescue team arrives on the scene [7]. But these recommendations are based on a nonphysician-led system, with no aggressive therapy on the scene, and on specific epidemiologic data. European guidelines, in contrast, seem to recognize the interest of aggressive therapy for these patients [8]. Lockey proposed therefore recently an algorithm to guide the effective management of TCA [21]. Our results seem to confirm the trend toward improved survival mentioned in these latest European recommendations. And concerning these results, the organization of hospitals in our network as a Trauma System since 2008 (TRENAU: Trauma System of the North Alpine Emergency Network) with care protocols (on-the-scene blood transfusion or thoracostomy) and a classification of hospitals according to their capabilities should allow optimizing TCA resuscitation initiation, care, and triage.

Our geographic area has indeed two specificities: a very low rate of penetrating trauma (7.6%) (one case in this series, with an outcome of brain death) and a remarkable rate of TCA from rural or mountain activities (18%), with often difficult and prolonged prehospital care. However, helicopter transport and sometimes the use of a mechanical chest compression device have proved effective in reducing time to admission [22].

In our study, 22% of TCA admitted to the hospital with circulatory activity were brain-dead and 11% became eventually organ donors. Most of them had asystole as the initial rhythm, and yet the quality of their organs was good, with an excellent functional outcome after 1 year.

Previous studies show that the quality of organs recovered from resuscitated CA patients seems to be as good as that from patients without a cardiac arrest [23]. The ischemia-reperfusion does not appear to affect the functioning of transplanted organs. Two authors even found a nonsignificant trend in favor of superiority of organs from CA donors, suggesting a possible role of

ischemic preconditioning played by the low-flow period [3,24].

Furthermore, we found the same trend of noninferiority for transplantation of hearts from donors who recovered after CA [24].

The refusal rate from the patient or from relatives in our series is 27.3%. This result is consistent with regional (25.8% of all patients identified in the RENAU area) and national figures (30.6% refusal on the French territory during the 2004–2008 period) [16].

Organ donation after TCA deserves more interest: Raouf, in a paramedic-staffed prehospital system, studied 252 out-of-hospital and in-hospital TCA; 9% of them became organ donors after BD [25]. Moreover, our results suggest that of 100 out-of-hospital TCA, CPR performed by specialized prehospital medical teams on the scene will allow three patients to survive to discharge, and 11 to donate their organs.

It is not possible to calculate precisely the cost-effectiveness impact, but the benefits are clearly significant. Considering only kidney transplantation, the studies by Wolfe and Haller confirm the benefits of renal replacement therapy in terms of costs and quality-adjusted life year (QALY), regardless of the origin of the organs (living or deceased donors) [26,27]. Even if 34 instances of CPR (540/16) are needed to get one kidney transplanted, the low costs of out-of-hospital CPR still make it seem worthwhile.

In addition, the development of DCD programs in our country, and in the rest of the world, should highlight this pool of potential TCA donors among emergency teams: That is, a strong argument to promote TCA resuscitation [28].

Limitations

Our study was conducted in a specific population and area (few penetrating trauma, high number of mountain-related injuries), but with a population density and response times comparable to the average in metropolitan France. Many centers in our country have seen a significant reduction in the number of severe trauma because of a decrease in motor vehicle accidents, whereas our TCA prevalence is steady. Thus, our results cannot be a perfect reflection of the reality in France and Europe. The analysis of the new French national cardiac arrest registry, REAC, created in 2011, should help us confirm our results and estimate more precisely the pool of potential donors from out-of-hospital TCAs.

As many as 36 patients were initially classified as traumatic CA, but turned out to have experienced a medical CA, either because the loss of consciousness and fall resulting from the CA secondarily led to trauma, or because of misclassification in the register. This is a common problem

of prehospital etiological diagnosis: The physician on the scene may lack some history or studies to make an accurate diagnosis.

Two-thirds of the TCA in our study were declared dead on the scene after interruption of CPR. The lack of data in our register about the criteria for CPR withdrawal does not allow us to know whether aggressiveness and duration of CPR were optimal, while the best time to terminate resuscitation remains controversial [29].

Lastly, the registry is not exhaustive (only 81% of data were complete). While a rate higher than 75% is acceptable for a prospective registry, we are still missing some data for a number of CA patients [30].

Conclusion

Patients presenting with prehospital TCA should be resuscitated just as medical CA. Development of aggressive resuscitation therapies has led to an increase in survival over the last 10 years. The prevalence of TCA is steady in our network. Of 79 admitted TCA patients, 19% survived to discharge, 28% developed brain death, and 11% of those became organ donors. A total of 31 organs were transplanted, with no dysfunction in the first year post-transplantation. While the lists of patients awaiting transplant are getting longer, it is essential to raise awareness among prehospital and hospital teams to mounting evidence that out-of-hospital TCA are an organ source to be considered seriously.

Authorship

AF and DS: study supervision. DD, GD, and AG: data collection. AF and JJ: statistical analysis. KT, DS, and AA: critical revision of the article for important intellectual content.

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