CRITICAL CARE

Impact of emergency medical helicopter transport directly to a university hospital trauma center on mortality of severe blunt trauma patients until discharge

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the French Intensive Care Recorded in Severe Trauma

Abstract

Introduction: The benefits of transporting severely injured patients by helicopter remain controversial. This study aimed to analyze the impact on mortality of helicopter compared to ground transport directly from the scene to a University hospital trauma center.

Methods: The French Intensive Care Research for Severe Trauma cohort study enrolled 2,703 patients with severe blunt trauma requiring admission to University hospital intensive care units within 72 hours. Pre-hospital and hospital clinical data, including the mode of transport, (helicopter (HMICU) versus ground (GMICU), both with medical teams), were recorded. The analysis was restricted to patients admitted directly from the scene to a University hospital trauma center. The main endpoint was mortality until ICU discharge.

Results: Of the 1,958 patients analyzed, 74% were transported by GMICU, 26% by HMICU. Median injury severity score (ISS) was 26 (interquartile range (IQR) 19 to 34) for HMICU patients and 25 (IQR 18 to 34) for GMICU patients. Compared to GMICU, HMICU patients had a higher median time frame before hospital admission and were more intensively treated in the pre-hospital phase. Crude mortality until hospital discharge was the same regardless of pre-hospital mode of transport. After adjustment for initial status, the risk of death was significantly lower (odds ratio (OR): 0.68, 95% confidence interval (CI) 0.47 to 0.98, $P = 0.035$) for HMICU compared with GMICU. This result did not change after further adjustment for ISS and overall surgical procedures.

Conclusions: This study suggests a beneficial impact of helicopter transport on mortality in severe blunt trauma. Whether this association could be due to better management in the pre-hospital phase needs to be more thoroughly assessed.

Keywords: severe trauma patients, helicopter transport, pre-hospital care, mortality

Introduction

For severely injured patients, delayed control of hemorrhage is the main factor contributing to trauma mortality [1,2]. Direct access to a trauma center with definitive care reduces the risk of death [3]. Helicopter transport (HT) of the injured patient should improve access to the trauma center, but its use remains controversial [4]. Several studies have shown that trauma patients transported by helicopter are more severely injured, have longer transport times, and require more hospital resources than those transported by ground [5,6]. In recent large studies, HT was a predictor of survival compared with ground transport (GT) [7,8]. The debate about the factors that could explain the impact of HT on survival remains open [9]. This benefit could be attributed to a higher level of competence in helicopter

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crews or to improved care provided at the destination centers [10-12].

The French Intensive care Research in Severe Trauma (FIRST) is a multicenter cohort study of consecutive severe blunt trauma patients admitted to 14 University hospitals (UnivH) and ICUs within 72 hours of injury. A previous analysis demonstrated that pre-hospital medical management reduces 30-day mortality in severe blunt trauma compared with non-medical pre-hospital management [13].

The aim of this observational study was to evaluate the impact on mortality of injured patients within hospital discharge of HT versus GT directly from the scene to a UnivH trauma center.

Materials and methods
The French pre-hospital trauma rescue system
The French pre-hospital rescue system with the Mobile Intensive Care Unit (MICU) has been well described in the literature [13-15]. All MICUs are staffed by an emergency physician, a nurse, and a specially trained ambulance driver. The decision to use a helicopter (HMICU) is based on the suspected severity of the accident or trauma, distance from the trauma center, availability of the helicopter, and the suspected need for immediate recourse to a trauma center able to provide definitive care especially for specialized surgery. In France, ground MICUs (GMICUs) are staffed by a team from the closest hospital, while HMICUs are staffed by a team with an emergency physician from the regional University hospital. Both GMICUs and HMICUs can be dispatched simultaneously to the scene of the accident when necessary. The MICU may initiate early life-sustaining treatment at the scene of the accident and the patient is transported to the closest trauma center or to a UnivH trauma center [16,17]. When HMICU is dispatched to the scene of the accident, the injured patient is always transported by helicopter. The response to treatment and suspected severity is used by the dispatching physician to identify the most appropriate center for the patient [18]. Although there is still no formal certification process as described in some other Trauma Systems, the University hospitals can provide care in the same way as level one trauma centers in the United States, and are identified by the dispatching center as a regional trauma center.

Patients
Between December 2004 and March 2007, the data on consecutive patients with severe blunt trauma were prospectively recorded in 14 UnivH in France. Inclusion criteria were age 18 or above and suspected severe blunt trauma, defined as trauma requiring admission to a UnivH ICU within 72 hours of injury or, in the case of early death before ICU admission, trauma managed by the MICU of a UnivH. Exclusion criteria were penetrating trauma and death occurring before any advanced life-sustaining treatment was administered. A total of 3,205 patients were eligible for inclusion in the FIRST study [13].

Data collection
The eligibility criteria were checked online by the research assistants of the Coordination Center in Dijon (France). Every month, data were extracted by the Coordination Center for quality control. For missing, aberrant or illogical mandatory data, queries were sent to local research assistants. At the end of the inclusion period, data monitoring was performed by the Coordination Center to validate data quality on a random sample of 7% of patients. Unreliable variables were discarded from the analysis. The following data were collected: patient characteristics, data about the circumstances of the accident, condition of victims in traffic-related accidents, and rescue services mobilized for patient transport (ground or helicopter), hospital units involved in early care of the patient before admission to the ICU, clinical and biological data in the pre-hospital phase, at first hospital admission and at 24 hours and 72 hours after trauma, and clinical variables on patient discharge or death including all surgical procedures within the first 24 hours and until discharge or death within 30 days. During the pre-hospital phase, the following data were recorded: prehospital time defined as the time between the accident or the first call to the dispatch center and the hospital admission, initial physiological variables (systolic blood pressure (SBP), pulse oximetry (SpO_2)), pupil status, Glasgow Coma Scale (GCS) and life-sustaining treatments (venous line, fluid loading and catecholamine administration, tracheal intubation, ventilation, blood products, and chest tube insertion). The accident was considered potentially severe if, in the case of a road traffic accident, at least one of the following was present: pedestrian, no safety equipment (air bag, seat belt, crash helmet, and so on), excessive speed, victim ejected/crushed/burned/cut free from the vehicle, death of other victims in the vehicle, vehicle fall of more than six meters. For the other accidents, the potential severity was defined as a fall of more than six meters, or crushing by farm equipment. The accident was considered to have occurred in the daytime if it occurred between 8:30 am and 6:30 pm and at the weekend between 1:00 pm on Saturday and 8:00 am on Monday. The trauma was suspected to be serious if, on the initial medical examination, there was a suspicion of fractured skull or flail chest, spine injury or, in the presence of limb amputation, severe burns, smoke inhalation or mydriasis. Data were collected on hemostatic procedures including arterial embolization and hemostatic thoracotomy or abdominal laparotomy, as well as orthopedic procedures including all types of bone fixation of the

upper and lower limbs. For all patients, information on vital parameters and life-sustaining treatments was also collected upon arrival at the trauma center and 24 hours and 72 hours after the injury. Data were collected by ICU physicians and research assistants from the medical records of MICUs, emergency units and ICUs. The Abbreviated Injury Scale (AIS) was calculated according to the 1998 updated classification using medical, radiological and surgical reports. All problematic cases were reviewed by local ICU physicians.

The pre-hospital treatment was considered aggressive if at least three of the six life-sustaining treatments were administered during pre-hospital management (intubation, colloid and/or hypertonic saline solution infusion, continuous catecholamine infusion, pneumothorax aspiration or chest tube insertion, blood product administration and more than 1,000 ml of crystalloid infusion). All surgical procedures performed until ICU discharge were recorded and coded by physicians at the Coordination Center.

On patient discharge from the ICU or death (within 30 days), anatomic injury diagnoses with the corresponding AIS codes, and the ISS were collected [19-21].

According to French law (law 88-1138 relative to Biomedical Research of 20 December 1988 modified on 9 August 2004), this non-interventional study did not require approval by an Ethics Committee nor informed signed consent from the patients. The study was declared to, and approved by the French National Commission for Data Processing and Civil Liberties (authorization number 05-1059 obtained on 24 February 2005).

End points
The main outcome measurement was the vital status at 30 days or at ICU discharge, if discharge occurred within the first 30 days.

Statistical methods
Given their non-Gaussian distribution, quantitative variables were *a priori* categorized as follows: GCS score (<8, 8 to 13, >13), ISS (<15, 15 to 24, 25 to 34, ≥35), systolic arterial blood pressure (<90, 90 to 110, >110 mmHg), and SpO_2 (<90%, ≥90 %). Descriptive characteristics were expressed as percentages, or means with standard deviations (SD), or medians with IQR. Univariate comparisons between groups (HT versus GT) were performed using chi-square tests or Fisher exact tests, when appropriate, for qualitative variables, and using the Wilcoxon test for quantitative variables.

A multivariate analysis was performed using logistic regression stratified on the center, where the outcome (30-day mortality) was introduced as the dependent variable. Independent variables included mode of transport (ground or helicopter) and all pre-hospital covariables associated either with the mode of transport or

with 30-day mortality with a *P* value <0.20 in a bivariate analysis (model 1). For the covariable selection, we used a stepwise procedure excluding covariables with a *P* value greater than 0.10. A similar analysis strategy was used for further models that also included the ISS (model 2) and both the ISS and overall surgical procedures (model 3). Interaction terms between mode of transport and other independent variables were systematically tested. As none were significant, they were dropped from the final models. The Hosmer-Lemeshow test was used to check the models' goodness-of-fit (the *P* value was 0.33 for final model 1, 0.62 for final model 2 and 0.82 for final model 3). The discriminatory power of the models was quantified by the concordance index (C-index) corresponding to the area under the receiver operating characteristic (ROC) curve (C-index was 85.6% for final model 1, 87.7% for final model 2 and 88.2% for final model 3). The significance level was *P* <0.05. The statistical analyses were performed with SAS™ version 9.3 (SAS Institute Inc, Cary, NC).
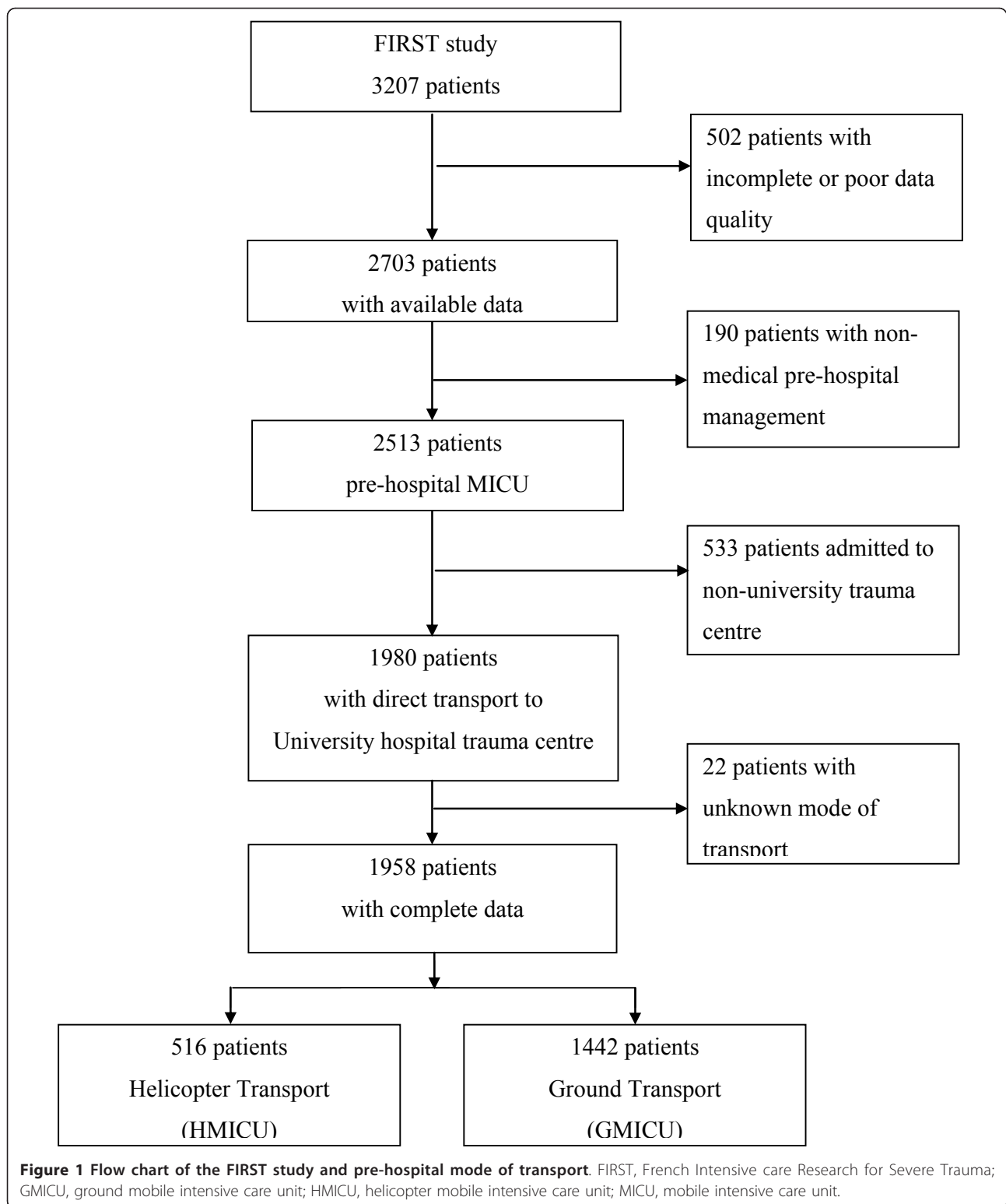
Results
Of the 1,958 patients directly admitted to a University trauma center with complete data, 74% were transported by ground and 26% by helicopter (Figure 1). Patient characteristics and accident circumstances are given in Table 1. A suspicion of severe trauma was significantly more frequent for HMICU than for GMICU. The median time to hospital admission was higher for HMICU than for GMICU (2.3 hours, IQR 1.8 to 3.0 versus 1.8 hours, IQR 1.3 to 2.3, *P* <0.0001).

Initial pre-hospital assessment and injury severity according to mode of transport are presented in Table 2. The proportion of patients with SBP lower than 90 mmHg was significantly higher in the HMICU group than in the GMICU group, as was the percentage of patients with severe spinal injury. The median ISS was 25 (IQR 18 to 34) for all patients, 26 (IQR 19 to 34) for the HMICU group and 25 (IQR 18 to 34) for the GMICU group. No differences in ISS were noted between the HMICU and GMICU groups.

The comparison of life-sustaining treatment administered during pre-hospital support is given in Table 3. HMICU patients were treated more aggressively than GMICU patients. Tracheal intubation, administration of crystalloids >1000 ml, treatment with catecholamines and blood product transfusion were more often observed in the HMICU group, whereas colloids or hypertonic saline solution (SSH) were more often used in the GMICU group.

The surgical procedures performed within 24 hours and until discharge from hospital according to mode of transport are presented in Table 4. Crude mortality before

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                                   │──────────────→ ┌──────────────────────┐
                                   │                │ 502 patients with    │
                                   │                │ incomplete or poor   │
                                   │                │ data quality         │
                                   ↓                └──────────────────────┘
                        ┌─────────────────────────┐
                        │    2703 patients        │
                        │   with available data   │
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                                   │
                                   │──────────────→ ┌──────────────────────┐
                                   │                │ 190 patients with    │
                                   │                │ non-medical          │
                                   │                │ pre-hospital         │
                                   ↓                │ management           │
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Figure 1 Flow chart of the FIRST study and pre-hospital mode of transport. FIRST, French Intensive care Research for Severe Trauma; GMICU, ground mobile intensive care unit; HMICU, helicopter mobile intensive care unit; MICU, mobile intensive care unit.

hospital discharge was no different according to pre-hospital mode of transport (88 patients: 17% in HMICU versus 283 patients: 19.6% in GMICU, $P = 0.20$). The risk of death was higher for men, day-time accidents (OR: 0.72, 95% CI 0.55 to 0.95, $P = 0.018$), potentially serious accidents and when there was a suspicion of severe trauma. No link was found between the time to hospital admission and mortality ($P = 0.96$).

Table 1 Patient characteristics and accident circumstances of patients with severe blunt trauma according to mode of transport.

	Transport modality, number (%)			
	All patients, number (%) number = 1,958	HMICU number (%) number = 516	GMICU number (%) number = 1,442	*P*
Age (years)				
median (IQR)	37.0 (24.9 to 52.8)	39.2 (25.1 to 52.9)	36.0 (24.8 to 52.8)	0.33*
mean (SD)	40.6 (18.0)	40.9 (16.9)	40.6 (18.4)	
Sex				
men	1,483 (75.7)	395 (76.5)	1,088 (75.5)	0.62
women	475 (24.3)	121 (23.5)	354 (24.5)	
Accident severity[a]				
Yes	1,278 (67.2)	317 (63.9)	961 (68.3)	0.073
No	680 (32.8)	199 (36.1)	481 (31.7)	
Suspected trauma severity[b]				
yes	994 (50.8)	286 (55.4)	708 (49.1)	0.014
no	964 (49.2)	230 (44.6)	734 (50.9)	
Accident time				
8:00 am to 6:30 pm	1,399 (72.5)	450 (87.7)	949 (67.0)	<0.001
Accident day				
week	1,366 (70.8)	336 (65.5)	1,030 (72.7)	0.002
weekend	563 (29.2)	177 (34.5)	386 (27.3)	
Time to hospital admission (hours)	number = 1,879	number = 507	number = 1,372	
median (IQR)	1.9 (1.4 to 2.5)	2.3 (1.8 to 3.0)	1.8 (1.3 to 2.3)	<0.001*
mean (SD)	2.4 (5.0)	3.1 (8.1)	2.1 (3.2)	

[a]Accident severity was defined if at least one of the following criteria was present: pedestrian; no safety equipment (air bag, seat belt, crash helmet, and so on); high velocity; victim ejected/crushed/burned/or cut free from the vehicle; death of another person in the same vehicle; fall of more than six meters. [b]Trauma severity was suspected if at least one of the following criteria was present: suspicion of skull fracture, pelvic fracture, flail chest, spine injury, limb amputation, severe burns, smoke inhalation, mydriasis. (*) Wilcoxon Test. GMICU, ground transport of mobile intensive care unit; HMICU, helicopter transport of mobile intensive care unit.

The multivariate analysis for evaluating the association between mode of transport and death before ICU discharge (within 30 days) was performed for 1,817 patients (Table 5). The risk of death was significantly lower (OR: 0.68, 95% CI 0.47 to 0.98, $P = 0.035$) for HMICU compared with GMICU (Table 5, model 1). Increasing age, GCS <14, SBP <90 mmHg, SpO_2 <90%, suspected trauma severity and aggressive therapy remained significant factors for death, whereas gender and time to hospital admission did not enter the regression model (model 1). The association between the mode of transport and mortality before discharge was unchanged after further adjustment for ISS (model 2), and by overall surgical procedures (model 3). Overall surgical procedures were associated with a reduction in the risk of death (P <0.001).

Discussion

This multicenter cohort study compared HT versus GT of severe blunt trauma patients, both with medical pre-hospital care delivered by MICU, and directly admitted to University hospitals. The probability of death before discharge was lower for helicopter medical transport compared with ground medical transportation. The median hospital admission time was higher for HMICU than

for GMICU patients, and the group transported by helicopter received a more aggressive pre-hospital treatment. This association between mode of transport and mortality until discharge was unchanged after further adjustment for ISS. HT was associated with a higher level of medical care and decreased mortality compared with GT.

Helicopters are a costly and limited resource, and their use must take into account their real benefit and risk [22]. Over-triage increases costs and may increase the risk of critical events for transport teams. Under-triage may lead to increased morbidity and mortality in patients who could have benefited from its use.

The present study was specifically performed to investigate the influence of the mode of transport, HT versus GT, on the outcome of injured patients in the context of a pre-hospital medicalized care. The fact that the ground team is identical to the helicopter team (physician, nurse and specially trained pilot/driver) makes it possible to analyze the potential benefit of pre-hospital medical care and its impact on outcome for several categories of patients with as little bias as possible [15]. To limit biases in this comparison, interfacility transfers were excluded and the analysis was restricted to patients directly admitted from the scene to a UnivH trauma

Table 2 Initial assessment and Injury Severity Score according to mode of transport.

		Mode of Transport; number (%)		
	all patients; number (%) number = 1,958	HMICU number = 516	GMICU number = 1,442	*P*
GCS				
≥14	892 (46.0)	224 (44.0)	668 (46.8)	0.39
8 to 13	393 (20.3)	101 (19.8)	292 (20.4)	
<8	653 (33.7)	184 (36.2)	469 (32.8)	
Abnormal pupils				
No	1,474 (76.5)	386 (75.8)	1,088 (76.7)	0.71
Yes	454 (23.5)	123 (24.2)	331 (23.3)	
SBP (mmHg)				
≥110	1,324 (68.3)	329 (65.0)	995 (69.5)	0.03
90 to 110	344 (17.8)	89 (17.6)	255 (17.8)	
<90	270 (13.9)	88 (17.4)	182 (12.7)	
SpO₂ (%)				
≥90	1,626 (84.8)	419 (84.5)	1,207 (84.9)	0.83
<90	292 (15.2)	77 (15.5)	215 (15.1)	
AIS				
head AIS ≥4	81 (41.4)	19 (38.6)	61 (42.4)	0.14
face AIS ≥4	1 (0.7)	7 (1.4)	6 (0.4)	0.05*
neck AIS ≥4	9 (0.5)	2 (0.4)	7 (0.5)	1*
thorax AIS ≥4	567 (29.0)	134 (26.0)	433 (30.0)	0.08
abdominal AIS ≥4	137 (7.0)	36 (7.0)	101 (7.0)	0.98
spine AIS ≥4	171 (8.7)	68 (13.2)	103 (7.1)	<0.001
upper limbs AIS ≥4	1 (0.1)	1 (0.2)	0 (0.0)	0.26*
lower limbs AIS ≥4	112 (5.7)	21 (4.1)	91 (6.3)	0.06
other AIS ≥4	2 (0.1)	0 (0.0)	2 (0.1)	1*
ISS				
15 to 24	457 (23.3)	116 (22.5)	341 (23.7)	0.31
25 to 34	725 (37.0)	207 (40.1)	518 (35.9)	
≥35	471 (24.1)	122 (23.6)	349 (24.2)	

* Fisher Exact Test; AIS, Abbreviated Injury Scale; GCS, Glasgow Coma Scale; GMICU, ground mobile intensive care unit; HMICU, helicopter mobile intensive care unit; ISS, Injury Severity Score; SBP, systolic blood pressure; SpO₂, pulse oximetry.

center able to provide definitive care for all trauma patients. Similarly, to investigate the real benefit of HT versus GT, patients transported by ground without pre-hospital medical care were excluded.

Patients with an ISS >15 are deemed to require specialized trauma care, while patients with an ISS of 15 or less are considered to have non-life threatening injuries [23,24]. The severity of trauma in the FIRST patients is

Table 3 Pre-hospital life-sustaining treatments according to mode of transport.

	Mode of Transport			
	all patients number (%) number = 1,958	HMICU number (%) number = 516	GMICU number (%) number = 1,442	*P*
Aggressive therapy[a]	287 (14.7)	97 (18.8)	190 (13.2)	0.002
(1)Tracheal intubation	1,050 (53.6)	308 (59.7)	742 (51.5)	0.001
(2) Colloids or SSH	1,074 (54.9)	238 (46.1)	836 (58.0)	<0.001
(3) Crystalloids ≥1000 ml	431 (22.0)	131 (25.4)	300 (20.8)	0.031
(4) Catecholamines	261 (13.3)	93 (18.0)	168 (11.7)	<0.001
(5) Blood products	72 (3.7)	43 (8.3)	29 (2.0)	<0.001
(6) Exsufflation or chest tube	38 (1.9)	14 (2.7)	24 (1.7)	0.14

[a]Aggressive therapy: if three or more of criteria (1) to (6) were present. GMICU, ground mobile intensive care unit; HMICU, helicopter mobile intensive care unit; SSH: hypertonic saline solution.

Table 4 Surgical and hemostatic procedures performed within 24 hours and before discharge from hospital according to mode of transport.

		all patients; number(%) number = 1,958	HMICU; number(%) number = 516	GMICU; number(%) number = 1,442	P
Total surgical procedures	within 24 hours	909 (46.4%)	252 (48.8%)	657 (45.6%)	0.20
	overall	1,414 (72.2%)	397 (76.9%)	1,017 (70.5%)	0.005
Head procedure					
Craniotomy	within 24 hours	98 (5.0%)	24 (4.7%)	74 (5.1%)	0.67
	overall	126 (6.4%)	29 (5.6%)	97 (6.7%)	0.38
ICP/EVD	within 24 hours	-	-	-	<0.001
	overall	329 (16,8%)	111 (21.5%)	218 (15.1%)	
Face surgery	within 24 hours	70 (3.6%)	23 (4.5%)	47 (3.3%)	0.21
	overall	198 (10.1%)	66 (12.8%)	132 (9.2%)	0.019
Thoracic surgery					
thoracotomy	within 24 hours	36 (1.8%)	7 (1.4%)	29 (2.0%)	0.34
	overall	46 (2.4%)	11 (2.1%)	35 (2.4%)	0.71
chest tube	within 24 hours	-	-	-	-
	overall	330 (16.9%)	95 (18.4%)	235 (16.3%)	0.27
Abdominal surgery	within 24 hours	162 (8.3%)	46 (8.9%)	116 (8.0%)	0.54
	overall	219 (11.2%)	69 (13.4%)	150 (10.4%)	0.067
Spine stabilization	within 24 hours	130 (6.6%)	52 (10.1%)	78 (5.4%)	<0.001
	overall	176 (9.0%)	68 (13.2%)	108 (7.5%)	<0.001
Bone limb fixation	within 24 hours	574 (29.3%)	140 (27.1%)	434 (30.1%)	0.21
	overall	654 (33.4%)	168 (32.6%)	486 (33.7%)	0.64
Wound surgery	overall	364 (18.6%)	97 (18.8%)	267 (18.5%)	0.89
Other surgery	overall	42 (2.2%)	17 (3.3%)	25 (1.7%)	0.036
Pelvic stabilization	within 24 hours	35 (1.8%)	6 (1.2%)	29 (2.0%)	0.22
	overall	53 (2.7%)	13 (2.5%)	40 (2.8%)	0.76
Angiography					
alone	within 24 hours	-	-	-	-
	overall	71 (3.6%)	21 (4.1%)	50 (3.5%)	0.53
with embolization	within 24 hours	-	-	-	-
	overall	123 (6.3%)	32 (6.2%)	91 (6.3%)	0.93
Total hemostatic procedures	Within 24 hours	228 (11.6%)	61 (11.8%)	167 (11.6%)	0.89
	overall	279 (14.3%)	81 (15.7%)	198 (13.7%)	0.28

EVD, external ventricular derivation; GMICU, ground mobile intensive care unit; HMICU, helicopter mobile intensive care unit; ICP, intracanial pressure.

attested to by the high median ISS and the high percentage of patients with an ISS above 35 (about 25% of all patients). The trauma severity was not different between HMICU and GMICU groups. The percentage of patients with severe spinal injury was higher in the HMICU group than in the GMICU group. The preferred choice of helicopter in cases of spinal injury is probably explained by the higher level of comfort provided by HT.

The median time to hospital admission was longer for HMICU than for GMICU. There is controversy concerning the time spent on the scene and pre-hospital management. The possibility that shortening pre-hospital times improves survival has not yet been demonstrated in studies with appropriate statistical control [25]. Several large studies have demonstrated that, despite a longer transport time associated with HT, trauma patients are more likely to survive and/or to be discharged and allowed to

go home after treatment [5,8,26]. This delay may be partly due to a more aggressive therapy observed in HMICU compared with GMICU during the pre-hospital phase. Aeromedical teams usually provide a higher level of care than GMICU teams. Several factors may explain this difference. First, helicopter teams from University hospitals should be more specialized and more highly trained in the care of severely injured patients [27,28]. Helicopter teams usually have a higher level of experience than the GMICU of the nearest hospital for primary care of severe trauma patients. In addition, the decision to administer life-sustaining treatment before HT must be anticipated because of the complexity of performing procedures during the flight.

Few studies have demonstrated a real benefit of high level pre-hospital care. Endotracheal intubation and tension pneumothorax decompression on the scene have been shown to reduce early deaths in trauma [29]. Initial

Table 5 Association between transport modality and death before ICU discharge (within 30 days) in multivariable analysis

	Model 1			Model 2			Model 3		
	OR	95% CI	*P* value	OR	95% CI	*P* value	OR	95% CI	*P* value
Pre hospital transport									
GMICU	1	-		1	-		1	-	
HMICU	0.68	0.47-0.98		0.67	0.46-0.97		0.68	0.47-0.99	
Age			<0.001			<0.001			<.001
(for 1 year variation)	1.03	1.03-1.04		1.04	1.03-1.04		1.04	1.03-1.04	
Glasgow Coma Scale			<0.001			<0.001			<.001
≥14	1	-		1	-		1	-	
8 to 13	2.67	1.67-4.26		2.33	1.44-3.77		2.26	1.39-3.68	
<8	13.37	8.97-9.91		10.84	7.20-16.31		10.11	6.67-15.32	
Systolic blood pressure (mmHg)			<0.001			<0.001			<.001
≥110	1	-		1	-		1	-	
90 to 109	1.43	0.95-2.15		1.23	0.81-1.88		1.37	0.89-2.09	
<90	2.79	1.90-4.10		2.5	1.69-3.71		2.49	1.66-3.73	
SpO$_2$ (%)			0.001			0.001			0.001
>90	1	-		1	-		1	-	
<90	1.83	1.27-2.63		1.83	1.27-2.64		1.89	1.29-2.75	
Day time			0.012			0.017			0.021
Day	1	-		1	-		1	-	
Night	0.65	0.46-0.91		0.65	0.46-0.93		0.66	0.46-0.94	
Aggressive therapy[b]			0.023			0.066			0.099
No	1	-		1	-		1	-	
Yes	1.54	1.06-2.24		1.44	0.98-2.11		1.39	0.94-2.06	
Trauma severity			0.031	not entered		(p>0.10)	not entered		(p>0.10)
No	1	-		-	-		-	-	
Yes	1.4	1.03-1.90		-	-		-	-	
Injury Severity Score	not entered					<0.001			<.001
<15	-	-	-	1	-		1	-	
15 to 24	-	-	-	0.77	0.37-1.60		6.54	3.35-12.76	
25 to 34	-	-	-	2.59	1.37-4.89		3.34	1.74-6.43	
≥ 35	-	-	-	4.8	2.51-9.15		0.87	0.41-1.83	
Surgery (overall)	not entered			not entered					<.001
No	-	-	-	-	-	-	1	-	
Yes	-	-	-	-	-	-	0.34	0.24-0.48	

[a]Analysis performed among 1,817 patients due to missing values for at least one covariate; [b]therapy defined as aggressive if at least three of six criteria were present: tracheal intubation, colloids or SSH, crystalloids ≥1000 ml, catecholamines, blood products, exsufflation/chest tube. CI, confidence interval; GMICU, ground mobile intensive care unit; HMICU, helicopter mobile intensive care unit; OR, odds ratio; SpO$_2$, pulse oximetry; SSH, hypertonic saline solution.

management of patients with severe blunt head trauma requires aggressive volume resuscitation and active drugs to maintain cerebral perfusion pressure, which is directly related to mean arterial blood pressure. The impact of life threatening measures by paramedics on outcome is not clear. The OPALS Major Trauma Study showed that system-wide implementation of full advanced life support programs for paramedics does not decrease mortality or morbidity in major trauma patients [30]. Therefore, the major benefit of HMICU seems to be the high rate of early intervention by medical air teams, the quality of life-sustaining treatment and decision-making and a more aggressive on-site approach [10,29,31]. A better outcome with this strategy has been described for severe traumatic brain injury [11].

Our results showed that the need for emergency surgical procedures, and overall head surgical procedures until discharge from hospital, was higher in the HMICU group than in the GMICU group. Although crude mortality until hospital discharge was no different according to pre-hospital mode of transport, the probability of death before hospital discharge was lower for the HMICU group in the multivariate analysis, whatever the model considered. HT seems to act as an accelerator of care within the hospital, probably with a higher quality of care by the team in charge of the patient on arrival at the trauma center.

Our study must be interpreted with caution because of its methodological limitations. The FIRST study is observational so that no causal inference can be drawn from our findings. The decision to dispatch a helicopter is based on multiple factors, and there is currently no standardization of these criteria in France. There may thus be differences between the various centers in how this mode of transport is chosen. Hospitals participating in the FIRST study were UnivH. These trauma centers were able to provide definitive care, but the level of care for each patient may have been different in the absence of procedures validating the ability of staff to manage all trauma patients. However, to take into account potential between-center differences in patient management, all analyses were stratified by center. Another weakness was our limited ability to distinguish between urban and rural intervention areas which may influence the use of HT. Furthermore, the distance from the scene of the accident to the trauma center was not recorded, and we were unable to distinguish the time dedicated to transport and the time for performing life-sustaining treatment by the team. Despite our careful adjustment strategy, we cannot exclude residual confounding due to non-measured factors such as comorbidities and detailed schedule of pre-hospital care. A further limitation of this study was the lack of information on patient quality of life. Helicopters may reduce mortality rates, leaving patients disabled and with a lower quality of life in the long-term. Finally, our study was conducted only in patients who were managed by MICU prior to hospital admission; this is not the case for all pre-hospital systems, making it difficult to generalize about our results.

Conclusions
This original comparison of helicopter utilization in the pre-hospital context shows that severe trauma patients transported by helicopter medical teams received more aggressive therapy during the pre-hospital phase than patients transported by ground medical teams. Their probability of death was decreased with HT after adjustment for initial physiological status and trauma severity compared with patients transported by GMICU. It remains unclear whether or not this benefit can be attributed exclusively to the high level of pre-hospital care. More aggressive therapy during the pre-hospital phase and more overall surgical procedures during the hospital phase cannot alone explain this benefit. Furthermore, more detailed analysis of the pattern of pre-hospital care is needed to explore other factors that may help to explain this benefit. Finally, HT is more expensive than GT and a cost effectiveness analysis may be the most appropriate step for further studies.

Key messages
- HMICU patients had a higher median time frame before hospital admission
- HMICU patients were more intensively treated in the pre-hospital phase
- After adjustment for initial status, the risk of death was significantly lower for HMICU compared with GMICU
- This study suggests a beneficial impact of HT on mortality in severe blunt trauma
- Whether this association could be due to better management in the pre-hospital phase needs to be more thoroughly assessed.

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Authors' contributions

TD was involved in the analysis and interpretation of data and drafted the manuscript. JMY was involved in the study design, in the acquisition of data and in the final revision of the manuscript. HC, CJ, MR, BV and CM participated in the acquisition and interpretation of data and in the final revision of the manuscript. CBK was responsible for the logistic coordination of the study, was involved in the design of the study, in statistical analysis and interpretation of data and helped to draft the manuscript. MF initiated and coordinated the study and was involved at all steps of the study. All authors read and approved the final manuscript.

Competing interests

The authors declare that they have no competing interests.

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