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Acting on the potentially reversible causes of traumatic cardiac arrest: Possible but not sufficient

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1

2 **Acting on the potentially reversible causes of traumatic**
3 **cardiac arrest: possible but not sufficient**

4

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18

19 **Abstract**

20 Introduction: Traumatic cardiac arrest (TCA) guidelines emphasize specific actions that aim
21 to treat the potential reversible causes of the arrest. The aim of this study was to measure
22 the impact of these recommendations on specific rescue measures carried out in the field,
23 and their influence on short-term outcomes in the resuscitation of TCA patients.

24 Methods: We conducted a retrospective study of all TCA patients treated in two emergency
25 medical units, which are part of the Northern Alps Emergency Network, from January 2004
26 to December 2017. We categorised cases into three periods: pre-guidelines (from January
27 2004 to December 2007), during guidelines (from January 2008 to December 2011), and
28 post-guidelines (from January 2012 to December 2017). Local guidelines, a physician
29 education programme, and specific training were set up during the post-guidelines period to
30 increase adherence to recommendations. Utstein variables, and specific rescue measures
31 were collected: advanced airway management, fluid administration, pelvic stabilisation or
32 tourniquet application, bilateral thoracostomy, and thoracotomy procedures. The primary
33 endpoint was survival rate at day 30 with good neurological status (cerebral performance
34 category scores 1 & 2) in each period, considering the pre-guidelines period as the
35 reference.

36 Results: There were 287 resuscitation attempts in the TCA cases included, and 279 specific
37 interventions were identified with a significant increase in the number of fluid expansions
38 (+16%), bilateral thoracostomies (+75%), and pelvic stabilisations (+25%) from the pre- to
39 post-guidelines periods. However, no improvement in survival over time was found.

40 Conclusion: Reversible measures were applied but to a varying degree, and may not
41 adequately capture pre-hospital performance on overall TCA survival.

42

43 **Keywords:** Advanced Life Support, Trauma, Cardiac Arrest

44

45 **Introduction**

46

47 Cardiopulmonary resuscitation (CPR) guidelines are probably the most widely implemented,
48 and best-known guidelines in medicine, particularly for sudden cardiac arrest. However,
49 traumatic cardiac arrest (TCA) guidelines are less known. After a period when resuscitation
50 of TCA was deemed futile (1-3), the international guidelines have reinvented this field based
51 on studies showing the value of specific measures aimed at treating the underlying
52 pathology, reflecting the more common causes of TCA including hypovolaemia, hypoxaemia,
53 tension pneumothorax, and cardiac tamponade. In 2008, the Northern French Alps
54 Emergency Network (RENAU) proposed local recommendations for TCA management. These
55 guidelines are a challenge for emergency medical services (EMSs) in terms of
56 implementation, dissemination, and training. The aim of this study was to measure the
57 impact of these recommendations on the specific rescue measures carried out in the field,
58 and their impact on short-term outcomes in the resuscitation of patients with a pre-hospital
59 TCA treated by emergency medical units.

60 **Methods**

61 We conducted a retrospective study of all TCA patients admitted to two emergency medical
62 units that formed part of the Northern French Alps Emergency Network (emergency medical
63 units of Annecy, and St Julien) from January 2004 to December 2017.

64 • *Data collection*

65 The Northern French Alps Emergency Network comprises all hospitals in three counties
66 (Isère, Savoie, and Haute-Savoie), including 13 Mobile Emergency, and Resuscitation
67 Services. The cardiac arrest registry of the Northern French Alps (RENAU AC) is an exhaustive
68 registry which follows the Utstein Style, and is set in a mountain area. It has been previously

69 described by Ageron et al. (4,5). Since 1 January 2004, each out-of-hospital cardiac arrest
70 (OHCA) case has been recorded in an electronic form completed by the emergency physician
71 in charge of the patient, and the dispatch centre. In 2008, the Northern French Alps
72 Emergency Network developed local guidelines to improve survival in TCA (Supplementary
73 material 1). A physician education programme, and specific training were set up to increase
74 adherence to recommendations. The training of all practitioners was completed over several
75 years. At the same time, the network established a trauma system, and a university degree
76 for the care of severe trauma cases (6).

77 In order to extensively describe TCA management, we focused the sample on two
78 emergency medical units (Annecy, and St Julien) that have collected data on specific pre-
79 hospital rescue measures.

80 • *Variables*

81 Utstein relevant variables such as age (continuous), gender (male or female), bystanders
82 present (yes or no), bystander CPR (yes or no), location of OHCA (home or not), shockable
83 rhythm (yes or no), intervention times, and advanced airway management (yes or no) were
84 included.

85 Specific rescue measures in TCA were also collected: fluid administration (expansion >250 ml
86 or not), pelvic stabilisation (yes or no), tourniquet application (yes or no), bilateral
87 thoracostomy (yes or no), and results in three categories: not performed, performed with
88 the presence of a TPx, performed without a TPx, as well as thoracotomy procedures.

89 For the purpose of this study, the period from January 2008 to December 2011 is considered
90 to be the guidelines period. The period between January 2004, and December 2007 is the
91 pre-guidelines period, and the post-guidelines period spanned from January 2012 to
92 December 2017.

93 • *Outcomes*

94 Patient status (alive/dead, and using standardised cerebral performance category [CPC]
95 score) was obtained at day 30 from the receiving unit or via phone interviews with research
96 associates if hospital discharge had occurred. When creating the registry, the ethics
97 committee validated this method of monitoring patient survival. The primary endpoint was
98 survival rate at day 30 with good neurological status (CPC 1 & 2). The secondary endpoint
99 was the rate of return of spontaneous circulation.

100

101 • *Statistical analyses*

102 Due to the low number of events, Fisher's exact, and Wilcoxon tests (categorical and
103 continuous variables, respectively) were used to compare the three time periods, using the
104 pre-guidelines period as the reference. Statistical Analysis Software (v9.4, SAS Institute Inc.,
105 Cary, NC, USA) was used for the analyses. A $P < 0.05$ was considered statistically significant.
106 The study complied with the Declaration of Helsinki, and was approved by the ethics
107 committee of the University Hospital of Clermont-Ferrand, Clermont-Ferrand, France (IEC
108 no. 5891).

109

110

111 **Results**

112

113 Overall results

114 During the study period, 23,772 cardiac arrests were recorded in the RENAU cardiac arrest
115 registry, including 14% TCAs. A total of 3,856 OHCA cases were seen by the two emergency
116 medical units. Of those, 2,694 resuscitations were performed, and there were 287 patients

117 with TCA. The distribution of these 287 TCAs according to period is presented in Figure 1. A
118 total of 285 of these patients (99.3%) were in cardiac arrest when the EMS staff arrived on
119 the scene, the last two patients corresponding to cardiac arrest occurring during EMS
120 management in the pre-guidelines period. In 172 (59.9%) cases, bystanders were present at
121 the time of the event, and in 79 (27.5%) cases, bystanders began CPR without delay (Table
122 1). The initially monitored heart rhythm was pulseless electrical activity in 9% of cases
123 (n=22), asystole in 79.4% (n=228), ventricular fibrillation in 7.7% (n=22), and ventricular
124 tachycardia in one (0.35%) case. The mean time from call to arrival at patient was 12.1 ± 7.8
125 min. The main mechanisms were road and traffic injuries (n=136, 47.4%) and falls (n=92,
126 32.1%), far more frequent than penetrating wounds (n=18, 6.3%).

127 Endotracheal Intubation (ETI) was attempted in all cases. Out of the 287 cases, there were 7
128 failures (2.0%), 2 cases in the guidelines period, and 5 in the post-guidelines period. If
129 advanced airway support could not be provided, then basic airway support using airway
130 adjuncts, and bag-valve-mask ventilation was performed. Pre-hospital specific rescue
131 measures were identified in 279 cases (Table 2). During the study period, no transfusion or
132 thoracotomy was performed in the pre-hospital setting.

133 Favourable functional survival (CPC 1 & 2) at day 30 was observed for 8 (2.8 %) out of 287
134 patients. Primary, and secondary endpoints for each specific pre-hospital rescue measure
135 are presented in Table 2. Thoracostomy was performed in 175 (61.0%) cases, pelvic
136 stabilisation in 41 (14.3%) cases, tourniquet application in 5 (1.4%) cases, and fluid
137 expansion in 262 (91.3%) cases. Though the number of subjects was low, bilateral
138 thoracostomy in the event of pneumothorax, and tourniquet application were associated

139 with the primary endpoint. Thoracostomy performed without pneumothorax showed no
140 association with a favourable or unfavourable prognosis (Table 2).

141 **Discussion**

142 Our study shows that the implementation of guidelines is possible, it did not lead to
143 improvement in survival in our case series.

- 144 • Guidelines promoted implementation of specific measures

145 Contrary to the recommendations of medical aetiology in OHCA that have simplified over
146 time to improve their application, TCA management after prioritising basic, and advanced
147 life support must also take into account potentially reversible causes (7, 8). Such
148 management requires clear guidelines which provide detailed instructions on how
149 resuscitation should be performed (9,10). In this study, developing local guidelines, physician
150 education, and specific training increased adherence to recommendations. The percentage
151 of tourniquet applications, pelvic stabilisations, and systematic achievement of bilateral
152 thoracostomy has improved over time in the last period. Similarly, the systematic fluid re-
153 expansion that was common practice before the guidelines was optimised. A possible
154 explanation for this optimisation would be the prevalence of TCAs in our network, which is
155 the most common non-medical aetiology for cardiac arrest, as well as the creation of a
156 trauma network in 2008 (11).

157 On the other hand, resuscitative emergency thoracotomies, which enable definitive
158 treatment for traumatic cardiac tamponade, have never been implemented in our network.
159 Most cases of cardiac tamponade are secondary to penetrating trauma, and are rarely

160 described in France. In our specific geographical area, there is a very low rate of penetrating
161 trauma (7.6%), and a remarkable rate of TCA from rural or mountain activities (18%), with
162 often difficult, and prolonged pre-hospital care (12). This is in contrast with the United
163 States, where penetrating trauma may represent up to 30% of trauma patients, and 45% of
164 cardiac arrest patients (13). Thoracotomy is effective if it is carried out within a short
165 timeframe (14), which is not possible in our geographical area. In different European
166 countries, pre-hospital thoracotomy may be an option (15). In France, this technique is
167 currently only available in big cities such as Paris, Lyon, or Lille.

168 We chose a four-year guideline period, which may seem long, but we implemented an
169 educational programme, and trained all staff, which is a lengthy process. Said process is
170 beneficial since it aims to improve compliance with guidelines. Cabana et al. identified that
171 factors, such as training, can hamper implementation even after the decision to accept
172 guidelines has been made (16).

- 173 • No improvement in survival

174 Despite the increase in specific TCA rescue measures in our network, no improvement in
175 survival has been observed. Survival was even better before the guidelines were put in
176 place. This suggests that reversible measures may not adequately capture pre-hospital
177 performance on overall survival in TCA. There has been a similar paradoxical effect in
178 hospitals participating in the quality improvement registry for in-hospital cardiac arrest
179 (IHCA), and Get With The Guidelines (GWTG). These hospitals received a gold medal for
180 $\geq 85\%$ compliance for all four metrics for IHCA: time to chest compressions ≤ 1 minute; time
181 to defibrillation ≤ 2 minutes; device confirmation of endotracheal tube placement during an

182 acute resuscitation; and ensuring a monitored or witnessed cardiac arrest. Despite
183 excellence in these resuscitation performance metrics, these measures do not accurately
184 classify hospitals with the highest rates of survival to discharge for in-hospital cardiac arrest
185 (17).

186 The TCA guidelines include a long list of interventions for advanced cardiovascular life
187 support (ACLS) algorithms aside from continuous chest compressions, and defibrillation. The
188 predictable result of this complex algorithm (Additional files 1) is that it possibly favours the
189 number of interrupted chest compressions (18), and patients who had longer periods
190 without chest compressions had poorer resuscitation outcomes.

191 In 2008, the OPALS study group suggested that advanced life support (ALS) practices are not
192 necessarily correlated with improved survival in trauma, and cardiac arrest (19). However,
193 the context of this study is different, since it is based on databases designed for different
194 purposes (Cardiac Arrest Registry, and Trauma Registry). The Cardiac Arrest Registry is a
195 recording system triggered by the cardiac arrest code, whereas, in the presence of trauma,
196 cardiac arrest usually represents the exit code.

197 It is likely that implementing specific measures without considering the performance of
198 other critical resuscitation practices that are strong determinants of OHCA survival may
199 explain these results. Specifically, during cardiac arrest resuscitation, practices that are
200 believed to be strong predictors of survival include high-quality cardiopulmonary
201 resuscitation (including depth, and frequency of chest compressions), and minimising
202 interruption times of chest compressions (20,21). Moreover, excellence in post-resuscitation
203 care among patients who survive acute resuscitation likely plays a large role (22,23). Also,

204 the severity of trauma was not considered, which is reported to be a determinant of survival
205 since a high severity score (over 25) may indicate poor prognosis after TCA (24,25).

206 During the pre-guidelines period, two cardiac arrests occurred in two patients during EMS
207 management, and one of them survived. Several studies show that the prognosis is
208 improved in these situations (26,27). Also, during the post-guidelines period, despite TCA
209 occurring more often in front of witnesses, we observed less bystander presence, and less
210 shockable rhythm. In a meta-analysis by Tran et al., the presence of a shockable initial
211 cardiac rhythm in TCA is one of the most important predictors of survival with an odds ratio
212 of 7.29 (28). Given the small number of survivors in our study, these factors may have
213 partially influenced the results.

214 Intubation difficulties have especially come into play in the guidelines, and post-guidelines
215 period. These unsuccessful attempts may have been accompanied by less sustained
216 attention to the quality of continuous chest compressions.

217 Even if the percentage of thoracostomies with pneumothorax in our cardiac arrest group
218 was 15.3% (44/287), which is slightly higher than in the Berlin cohort (13%) (26), it decreased
219 in the post-guidelines period. Several publications have claimed that implementation is too
220 rare (7,29).

221 Finally, in our network we observed that survival of out-of-hospital cardiac arrest due to any
222 cause is surfing on the guidelines wave (30). After four years, survival decreased. This
223 decrease in survival could also be linked to the quality of CPR provided by first responders,
224 but unfortunately the registry did not collect data on this. This is very different from the

225 studies that found increased survival following OHCA after implementing guidelines in a non-
226 traumatic context (31,32).

227 Our study has several limitations. Firstly, it was conducted in a specific population, and area
228 with few penetrating traumas, and a high number of mountain-related injuries. In many
229 centres in France, the rate of severe trauma is significantly lower because of a decrease in
230 motor vehicle accidents, whereas TCA prevalence in our area remains steady. Thus, our
231 results cannot be a perfect reflection of the reality in Europe or elsewhere. Secondly, since
232 this was a retrospective observational study, it may have been subject to a selection bias
233 relating to survival. In addition, TCA victims often have multiple injuries resulting in critical
234 hypoxaemia, TPx, or severe hypovolaemia, and our study only measures the effects of each
235 measure separately. Moreover, the number event per variable is low, and our results may
236 have a lack of power. The data came from a OHCA registry and characterization, severity of
237 injuries, localization was not available. Finally, the RENAU cardiac arrest registry is not
238 entirely exhaustive (only 81.8% of data was complete). While a rate higher than 75% is
239 acceptable for a prospective registry, we are still missing some data for a number of cardiac
240 arrest patients (12,33).

241 **Conclusion:**

242 The implementation of specific rescue measures in the resuscitation of TCA patients is
243 possible but insufficient to improve survival. Despite the importance of these measures,
244 which should be regularly supported with training, they are just one link in the chain of
245 survival in TCA.

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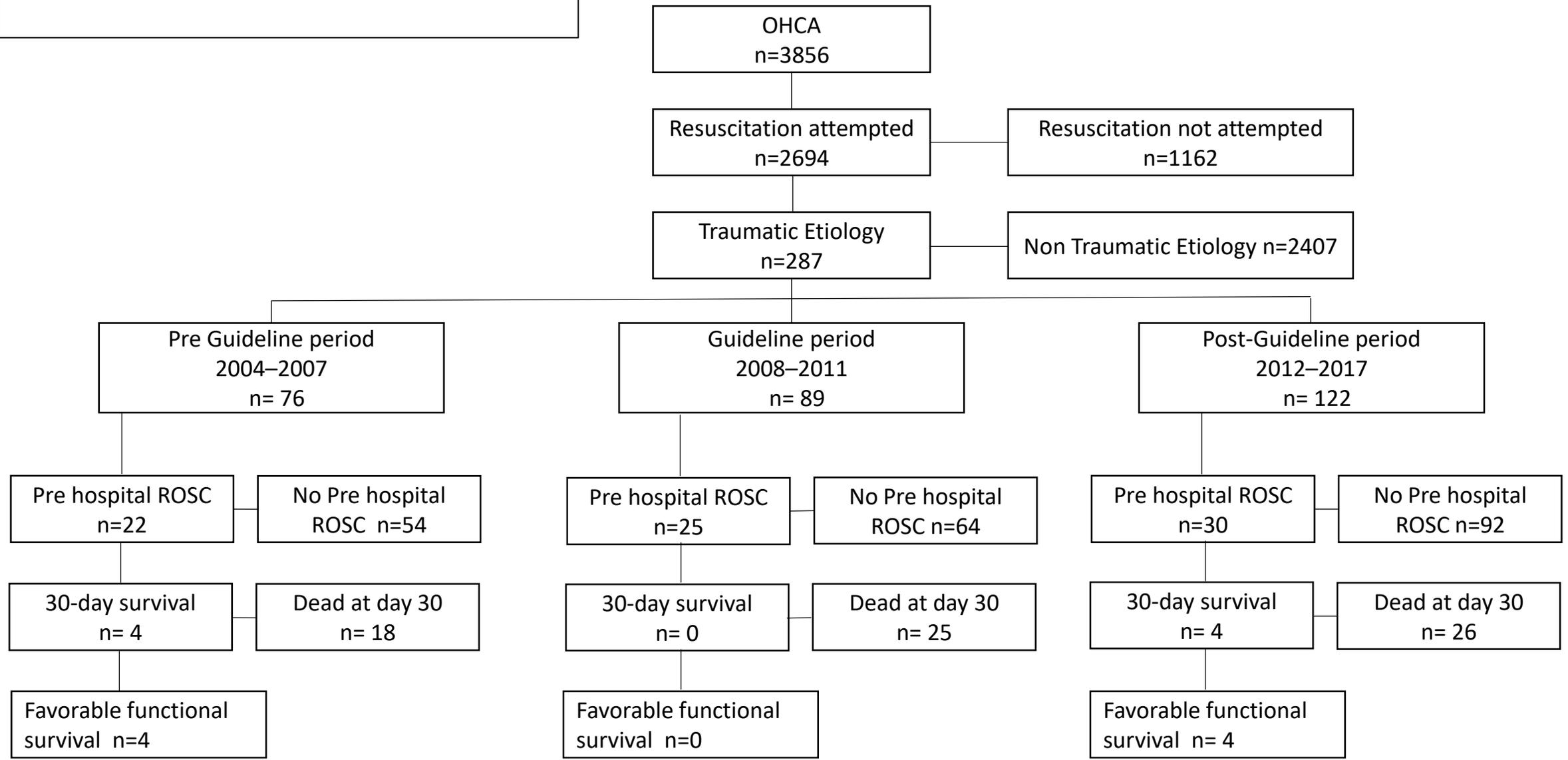
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Fig 1 – Flow chart of inclusion in the study



OHCA: Out of hospital cardiac arrest ROSC: Return of spontaneous circulation

Table 1. Comparison of patient characteristics in the three periods

	Pre-guidelines period 2004–2007 n=76	Guidelines period 2008–2011 n=89	Post-guidelines period 2012–2017 n=122
Age, mean (SD)	44.83 ± 20.98	47.12 ± 20.31	47.92 ± 20.31
Female, n (%)	12 (15.79)	13 (14.61)	30 (24.59)
Bystander present, n (%)	50 (72.46)	53 (70.67)	69 (71.88)
Shockable rhythm, n (%)	7 (9.21)	7 (7.87)	8 (6.56)
Bystander CPR, n (%)	16 (21.05)	26 (29.21)	37 (30.33)
Location at home, n (%)	14 (18.42)	11 (12.36)	17 (13.93)
Time from call to arrival at patient, mean (SD)	10.20 (10.05)	8.13 (11.05)	9.83 (13.14)

CPR: Cardiopulmonary resuscitation; SD: Standard deviation

*p<0.05, **p<0.01, ***p<0.001, ****p<0.0001, reference is the pre-guidelines period

Table 2. Comparison of trauma-specific additive measures, and outcome in the three periods

	Pre-guidelines period 2004–2007 n=76	Guidelines period 2008–2011 n=89	Post-guidelines period 2012–2017 n=122
Tourniquet, n (%)	1 (1.32)	0	4 (3.28)
Pelvic stabilisation, n (%)	0	10 (11.24)**	31 (25.41)****
Fluid expansion, n (%)	61 (80.26)	83 (93.26)*	118 (96.72)***
Bilateral thoracostomy, n (%)	5 (6.58)	70 (78.65)****	100 (81.96)****
- With tension pneumothorax, n (%)	3 (3.95)	18 (20.22)****	23 (18.85)****
- Without tension pneumothorax, n (%)	2 (2.63)	52 (58.43)****	77 (63.11)****
Return of spontaneous circulation n (%)	22 (28.95)	25 (28.09)	30 (24.59)
30-day survival	4 (5.26)	0****	4 (3.28)
30-day survival with good neurological status	4 (5.26)	0****	4 (3.28)

*p<0.05, **p<0.01, ***p<0.001, ****p<0.0001, reference is the pre-guidelines period