Improved pre-hospital care efficiency due to the implementation of pre-hospital trauma life support (PHTLS®) algorithms

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Abstract
Purpose Pre-hospital trauma life support (PHTLS®) includes a standardized algorithm for pre-hospital care. Implementation of PHTLS® led to improved outcome in less developed medical trauma systems. We aimed to determine the impact of PHTLS® on quality of pre-hospital care in a European metropolitan area. We hypothesized that the introduction of PHTLS® was associated with improved efficiency of pre-hospital care for severely injured patients and less emergency physician deployment.

Methods We included adult polytrauma (ISS > 15) patients that were admitted to our level one trauma center during a 7-year time period. Patients were grouped based on the presence or absence of a PHTLS®-trained paramedic in the pre-hospital trauma team. Group I (no-PHTLS group) included all casualties treated by no-PHTLS®-trained personnel. Group II (PHTLS group) was composed of casualties managed by a PHTLS® qualified team. We compared outcome between groups.

Results During the study period, 187,839 rescue operations were executed and 280 patients were included. No differences were seen in patient characteristics, trauma severity or geographical distances between groups. Transfer times were significantly reduced in PHTLS® teams than non-qualified teams (9.3 vs. 10.5 min, \(P = 0.006\)). Furthermore, the in-field operation times were significantly reduced in PHTLS® qualified teams (36.2 vs. 42.6 min, \(P = 0.003\)). Emergency physician involvement did not differ between groups.

Conclusion This is the first study to show that the implementation of PHTLS® algorithms in a European metropolitan area is associated with improved efficiency of pre-hospital care for the severely injured. We therefore recommend considering the introduction of PHTLS® in metropolitan areas in the first world.

Keywords Pre-hospital care · PHTLS · Polytrauma · Efficiency

Introduction

Pre-hospital trauma life support (PHTLS®) includes a standardized algorithm aiming to improve outcome of trauma patients by focusing on prioritizing medical demands in patients. PHTLS® was designed with the ideal that pre-hospital care standards should be in line with in-hospital standards of care. Content wise the guidelines differ from the preexisting German national guidelines regarding care of severely injured patients. The PHTLS® concept is trained by paramedics during a 2-day course and further includes a manual with all principles, algorithms and relevant background [1–3].

It is assumed that applying PHTLS® results in better communication between medical professionals, faster therapy and thereby improved survival. Previous studies in less
developed trauma systems showed improved outcome in severely injured trauma patients due to the introduction of PHTLS® guidelines [4]. In addition, studies under paramedics showed that PHTLS® courses lead to an increase in the subjective safety in pre-hospital care of trauma victims [5]. Nevertheless, clinical evidence on benefits of the implementation of PHTLS® guidelines in metropolitan areas in Western Europe is currently still lacking [6–8]. As in Western Europe there is a long tradition of optimizing and professionalizing pre-hospital treatment, there is a need to clarify whether the introduction of PHTLS® concepts results in additional benefits over the already existing pre-hospital care protocols or not [9]. Furthermore, it is unclear which specific processes of pre-hospital care are being affected by the implementation of PHTLS® guidelines.

So, the aim of this study is to determine the impact of the introduction of PHTLS® on efficiency of pre-hospital processing and transfer times as well as pre-hospital personnel requirements in a European metropolitan area.

We hypothesized that the introduction of PHTLS® in our region was associated with increased efficiency of pre-hospital care for severely injured patients and less emergency physician deployment.

Methods

Ethical approval

This study was performed in accordance with Good Clinical Practice guidelines, and ethical approval was obtained from the local medical ethical committee (KEK-ZH Nr. 2011-0493).

Patient selection

We included all adult polytrauma patients that were admitted to our level one trauma center during a 7-year time period (ending in 2014). Subjects were considered as polytrauma if they had an injury severity score [10] exceeding 15. All patients that were admitted by our local emergency transport service (Schutz & Rettung Zurich (SRZ)) to our institution (University Hospital Zurich) for primary stabilization and care were included. Transferred patients from other institutions were excluded. For the purpose of the study, we further excluded patients that attempted suicide by hanging, dead by drowning or mortality cases due to intoxication.

The emergency transport service Zurich is the largest civil rescue organization in Switzerland, and a total of 160 employees cover pre-hospital health care in the area of Zurich around the clock.

For this study, the following parameters were documented in our prospective database: NACA score [11, 12], transfer times, duration of out-of-hospital treatment, trauma location, the presence or absence of an emergency physician, age, gender and trauma severity.

Patient grouping

In our trauma region, PHTLS® was fully implemented in the year 2008. Between 2006 and 2013, emergency personnel was trained increasingly in the principles of PHTLS®. In order to test the impact of PHTLS® implementation on pre-hospital trauma team performance, we defined two study groups. Group I (no-PHTLS group) included all pre-hospital care situations in which none of the team member was trained in PHTLS®. Group II (PHTLS group) was composed out of those pre-hospital situations in which at least one team member completed the PHTLS® training.

Endpoints

In order to compare the efficiency of the pre-hospital procedures, we compared the following endpoints:

1. percentage of emergency doctor involvement
2. total operation time (time difference between the notification and arrival of the patient in the hospital)
3. in-field treatment time (time difference between the arrival of healthcare professionals on the spot and departure of paramedics, thereby reflecting the time period in which in-field care was provided)
4. transfer time (time difference between the time of trauma team departure from the trauma scene and hospital arrival time).

Additional data collection

In addition, we collected data on overall pre-hospital operations over time and related emergency physician involvement. We further gathered geographical data on pre-hospital cases over time. To do so, for all included patients the distance between the trauma location and our institution was calculated by using www.stepmap.de. Our institution is located in the city center. There are relevant geographical differences between the city center and rural areas in our region. Therefore, we compared the percentage of admissions from the center with admissions from outside the city center between groups. All trauma locations further than 10 km away from our institutions were considered as ‘rural’ scenarios, whereas those within 10 km from our institute are considered as ‘city center’ admissions.
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Statistical analysis

Statistical analyses were performed by using SPSS, version 20.0 (IBM, Chicago, USA), and GraphPad Prism (San Diego, USA). A P value < 0.05 was considered as statistically significant. T test was performed to test normally distributed continuous data, and otherwise, Mann–Whitney U tests were applied to compare differences between groups. Chi-square test was utilized to compare non-continuous variables.

Results

During the study period, a total of 187,839 ambulance runs were executed and annually 23,479 ± 1090 patients were transferred to our institute. Changes over time are shown in Fig. 1. Furthermore, in 6.04% of cases (N = 11,345) the emergency physician was required to support the local team on the spot.

In total, 280 patients with an ISS ≥ 16 were identified (representing 0.1% of all ambulance runs). The no-PHTLS group included 104 patients and 176 patients were treated by PHTLS-trained personnel (PHTLS group). Patients had a mean age of 44.5 years, and mostly male patients were identified. Mean age did not differ significantly between both groups (no-PHTLS 44.5 ± 20.8 vs. PHTLS 45.8 ± 20.7).

Furthermore, the encountered male predominance did not differ significantly between the no-PHTLS (72% male) and the PHTLS groups (72% male, P = 0.89).

Trauma severity did also not differ between groups. The mean NACA score in the no-PHTLS group was 4.45 ± 0.68, whereas a mean score of 4.51 ± 0.71 was found in the PHTLS cohort (P = 0.053). All baseline and trauma characteristics are summarized in Table 1.

Also, no statistical differences were found between the percentage of ‘rural’ trauma cases between groups. In total, 189 out of 280 patients were injured within the city center. No differences were found in non-city center admissions, between no-PHTLS and PHTLS casualties (P = 0.274). Moreover, transport distances also did not differ between study groups. A mean distance of 5.41 ± 3.25 km between the trauma location and our hospital was found in the no-PHTLS group, and a distance of 4.67 ± 3.03 km was calculated for PHTLS patients (P = 0.68).

We did not encounter statistically significant differences in emergency physician requirements between groups. Overall, in 121 cases (71.8%) an emergency physician was involved in the pre-hospital operation. In the no-PHTLS cohort, an emergency physician was required in 76.9% of cases (80/124 patients), and in the PHTLS group, a medical doctor had to support the team in the field in 68.8% of operations (121/176, P = 0.14).

When analyzing the efficiency of the applied pre-hospital care between groups, clear differences were found in encountered durations of pre-hospital operations.

The mean total operation time in our patients was 38.58 ± 17.37 min. In the absence of an emergency doctor, patients were admitted to our hospital in 28.59 ± 14.41 min and the transfer time in these individuals was 10.03 ± 7.32 min.

Mean in-field treatment times dropped significantly after the implementation of PHTLS® in our region. In the no-PHTLS group, out-of-hospital treatment in severely injured patients took 32.09 ± 15.56 min, whereas in the PHTLS teams, it only took 26.53 ± 13.26 min (P = 0.046). Thereby, PHTLS teams were 5.16 min faster than non-trained teams.

Furthermore, transfer times were also statistically significantly lower in casualties treated by PHTLS teams than no-PHTLS cases. Main transfer times in the no-PHTLS group of 10.53 ± 6.21 min were encountered, while transfer times of 9.30 ± 8.12 min were found in the PHTLS group (P = 0.006).

A striking decrease in total in-field operation times was found as well in patients treated by PHTLS-skilled teams, compared with untrained teams. Mean total operation times of 36.20 ± 17.27 min were found in PHTLS teams, whereas those of 42.59 ± 17.13 min were encountered in no-PHTLS teams (P = 0.003). Thereby, total pre-hospital care Efficiency was higher in the PHTLS cohort.

Table 1 Patient and trauma characteristics of both study groups

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>no-PHTLS</th>
<th>PHTLS</th>
<th>P value</th>
</tr>
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<tbody>
<tr>
<td>Age</td>
<td>44.5 ± 20.8</td>
<td>45.8 ± 20.7</td>
<td>0.69</td>
</tr>
<tr>
<td>Gender (%)</td>
<td>72%</td>
<td>72%</td>
<td>0.89</td>
</tr>
<tr>
<td>NACA Score</td>
<td>4.45 ± 0.68</td>
<td>4.51 ± 0.71</td>
<td>0.06</td>
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Fig. 1 Total number of physician involvements. Black bars represent total number of rescue operations, and gray bars represent total number of medical physician involvements.

Table 1 Patient and trauma characteristics of both study groups
The introduction of PHTLS® algorithms leads to a reduction in mortality in polytraumatized patients [4]. They revealed in Trinidad and Tobago that the introduction of PHTLS® algorithms improved prioritization indications for medical physician involvement change in the near future. As a consequence, in our view emergency doctor involvements may eventually drop as well due to PHTLS® implementation. Incidences of severely injured trauma patients are decreasing in Western Europe; thereby, the exposure of paramedics to life-threatening situations is decreasing as well. As a consequence, experience and routine of paramedics in treating severely injured patients diminish over time [1, 15]. PHTLS® training and the implementation of its protocols can compensate for this effect. It has been shown by Moorthy et al. that increased stress leads to increased failures. Interestingly, simulation training causes a reduction in stress levels in real clinical settings and thereby reduces failures as well [16, 17].

**Table 2** Comparison of performances of trauma teams between groups

<table>
<thead>
<tr>
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<th>no-PHTLS</th>
<th>PHTLS</th>
<th>P value</th>
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<tbody>
<tr>
<td>Total operation time (min)</td>
<td>42.59 ± 17.13</td>
<td>36.20 ± 17.27</td>
<td>0.003</td>
</tr>
<tr>
<td>In-field treatment time (min)</td>
<td>32.09 ± 15.56</td>
<td>26.53 ± 13.26</td>
<td>0.046</td>
</tr>
<tr>
<td>Transfer time (min)</td>
<td>10.53 ± 6.21</td>
<td>9.30 ± 8.12</td>
<td>0.006</td>
</tr>
</tbody>
</table>

was 6.39 min faster in severely injured patients treated by PHTLS-skilled teams compared with those patients treated by non-trained teams. Outcome is summarized in Table 2.

Moreover, in-field treatment was also faster in the PHTLS group in cases an emergency physician was on the spot (32.52 ± 16.36 min vs. 27.26 ± 12.23 min, \( P < 0.05 \)). This resulted in lower in-field treatment times of 3.49 min in the presence of an emergency doctor in post-PHTLS scenarios compared with pre-PHTLS cases. Total pre-hospital care in the presence of an emergency physician was also significantly faster in the PHTLS group compared with no-PHTLS patients, respectively, 37.47 ± 17.34 min vs. 44.40 ± 17.54 min (\( P = 0.006 \)). Besides, transport times decreased by 0.25 min in trained PHTLS teams in the presence of an emergency doctor.

**Discussion**

This study is the first to show that

1. the implementation of PHTLS® algorithms in a European metropolitan area is associated with decreased in-field operation times and increased on-spot efficiency of paramedics in the treatment of severely injured patients.
2. Utilizing PHTLS® algorithms is associated with improved efficiency of out-of-hospital care in the presence of an emergency physician as well.
3. However, on-spot requirement rates of an emergency physician are not altered due to the implementation of PHTLS® in the treatment of severely injured patients.

The results of our investigation are in line with a study from Ali et al. They revealed in Trinidad and Tobago that the introduction of PHTLS® algorithms leads to a reduction in mortality in polytraumatized patients [4]. They stated that the introduction of PHTLS® algorithms improved prioritizing capacities of the involved trauma teams and thereby diminished in-field treatment times [13]. In Western Europe, there is a long tradition of improving pre-hospital care and subsequent professional guidelines are available; therefore, the surplus of PHTLS® concepts had to be determined [7].

Previous analysis showed relevant differences in recommendations for severely injured patients between the PHTLS® guidelines and the most commonly utilized German trauma guidelines [1]. In our hospital, the German guidelines have been routinely utilized until PHTLS® was introduced, and with this study, we were the first to show that PHTLS® improved outcome and efficiency of pre-hospital care in a West European metropolitan setting.

Our findings are in contrast to work from Blomberg and colleagues. They did not find any improvements after the introduction of PHTLS® training on mortality or return to work after motor-vehicle traffic injuries in their observational study. This might be due to the heterogeneity of utilized dataset as PHTLS® training was implemented in the participating centers at different timepoints during the study period. Furthermore, because only motor-vehicle accidents were included in this study, the potential benefit for triage might be overlooked in this work as triage principles for motor-vehicle accidents are more straightforward than other trauma mechanisms [6].

Our study showed that on-spot treatment times did only reduce slightly following the implementation of PHTLS®. This can be explained by the fact that our emergency professionals were adequately trained (according to the German S3 guidelines) before the implementation of PHTLS® as well [9]. Therefore, the execution of initial life-saving actions itself most likely did not alter largely due to the PHTLS® training.

Nevertheless, by showing reduced total operation times in PHTLS®-trained teams, compared with teams without PHTLS® training experience, we proved the benefit of the PHTLS® program. Outcome in severely injured trauma patients is mostly determined by the care given in the first hour after insult, and therefore, this time period is known as the golden hour [14]. By reducing out-of-hospital stay of patients, they are faster enabled to be treated by optimal health care (under shock room or trauma bay conditions).

We did not find significant differences in medical physician involvement between pre-PHTLS and post-PHTLS groups; however, it might be due to PHTLS® implementation indications for medical physician involvement change in the near future. As a consequence, in our view emergency doctor involvements may eventually drop as well due to PHTLS® implementation.
Guenkel et al. showed that severely injured patients with craniocerebral injuries profit largely from short transfer times and the presence of an emergency doctor on-spot [18]. As total operation times are significantly shorter after the introduction of PHTLS®, this life-threatened group of patients is likely to benefit most from PHTLS® implementation.

Moreover, we believe that the implementation of PHTLS® results in a reduction in treatment costs of severely injured patients as the efficiency of procedures improves. Thereby, the costs to enroll the course and train the paramedics can be outweighed by the financial benefits of improved quality of pre-hospital care.

Limitations of this study include the absence of clinical outcome of individuals. Though, as outcome in polytrauma is the resultant of many consecutive steps at different stations (pre-hospital, trauma bay, operation room, intensive care), it is in our view not possible to correct adequately for all factors involved in the treatment chain. Therefore, a comparison of morbidity and mortality in our patients might result in suboptimal conclusions due to the inclusion of many confounders. The second limitation is that we excluded less severely injured patients and thereby potential benefits for these groups cannot be analyzed. This group was excluded as we aimed to optimize standardization in our study.

In conclusion, this study is the first to show that the implementation of PHTLS® algorithms in a European metropolitan area is associated with improved efficiency of paramedics in the treatment of severely injured patients. This effect is observed in both the absence and presence of an emergency physician. As outcome of severely injured patients is mainly determined by the care provided within the first hour following trauma, efficiency in transferring patients to level one trauma centers is a critical process. Therefore, we recommend considering implementing PHTLS® in metropolitan areas in the first world as well.

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

References