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ORIGINAL ARTICLE

Pre-hospital management of pediatric polytrauma during modern conflict: experience and limits of the French military health service

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Abstract

Background French military physicians serving in deployment are confronted with pediatric polytrauma patients (PPP) during the provision of medical aid to civilian populations. The objectives of this study were to describe the current care of PPPs during these missions, to report difficulties encountered and to evaluate the training of doctors for management of PPPs in the field.

Methods A descriptive epidemiological study based on a questionnaire sent to physicians who had been deployed overseas.

Results 91 doctors participated. Their mean age was 35 years. 86% of the doctors managed children whilst serving overseas, of which 54% were PPPs. The incidence of pediatric polytrauma varied according to the country, but overall from 1129 emergencies reported during overseas missions, 11% were PPPs. Penetrating traumas represented 37% of cases; 24% were circulatory distress and 19% were massive bleeding. 80% of the doctors reported a lack of pediatric trauma experience, less than 5% had received appropriate in-service training and only 9% had worked in pediatric emergency facilities in France. The equipment available for PPPs in the field was often poorly understood and frequently considered to be insufficient.

Conclusions The occurrence of PPPs of war is rare and complex, but care of older children it is similar to that required for adults. Preparation for PPP management, it could be optimized by identifying risks which alter depending on the country of deployment, such as the logistical organization of the battlefield chain of care. Improvements in doctors' pediatric trauma training should be individualized, based on their mission needs.

Level of evidence III.

Keywords Child · Polytrauma · Deployment · War · Pre-hospital

Background

Physicians of the French military health service (FMHS) care for children with multiple injuries, the collateral victims of armed conflicts. Their management is complicated and shaped by deployment conditions, the specificities of war trauma (e.g., shrapnel, burns or blasts) and differences between pediatric and adult care.

Reports exist about hospital management of pediatric polytrauma patients (PPP) in NATO Roles 2 and 3 [1–6], but

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we are unaware of publications describing pre-hospital pediatric trauma management. The objective of this study was to describe the current state of pediatric polytrauma patient management by French military physicians on deployment.

Methods

A multiple-choice, descriptive questionnaire, created in Word (Microsoft, Redmond, WA), was sent out to 500 physicians (generalist) who had been deployed to a conflict at least once by email in September 2015. They represent the entire physician population currently working in the French army and likely to be deployed. A child was defined as under the age of 18 years and a PPP was defined as an injured child as defined by at least one of the French Vittel's Criteria for Severe Trauma [7].

Data were collated using Excel (Microsoft, ibid.) and analyzed using R-Software (version 3.2.2, http://www.R-Project.org). Fisher's Exact Test was used to compare intergroup proportions. Correlations between the number of deployments and the management of PPP were calculated by the Spearman's rho rank correlation, because variables were ordinal; a rho value between 0 and 1 indicated a positive correlation. For the correlation between the location of deployment (country) and the management of PPPs, we used receiver operating characteristic (ROC) curves, because the objective was to compare quantitative and binary variables. The area under the curve (AUC) was considered positive if its value was ≥ 0.75, and significant if the lower value of its IC95 was greater than 0.5. A p value ≤ 0.05 was considered statistically significant.

Results

Study population

91 physicians responded to our questionnaire from the original 500; 6 were excluded because of zero deployment. Their mean age = 35 years (± 6; 27–58). The response rate was 76% but variable according to the items. The median number of deployments per physicians was 2.7 (± 2 SD, 0–10).

For those with less than 5 years' experience, the average number of deployment was 1.5. The most frequent locations were Mali and the Central African Republic. For those with 5–10 years' experience, the average number of deployments was 2.8. The most frequent deployments were to Afghanistan and the Central African Republic. Finally, for those physicians with more than 10 years' experience, the average number of deployments was 3.9 and mostly in Chad, Afghanistan or Mali.

Prevalence of PPPs

During their deployments, 86% of physicians reported treating children and 54% cared for PPPs. In total, 1129 medical emergencies (trauma and non-trauma) were reported: 722 involved adults; 282 were non-traumatized children and 125 were PPPs. Over the average 2.7 missions, each physicians responded to 13 emergencies (± 17.5), of which 4.7 (± 8.9) involved children and 1.5 (± 2.8) were PPPs. The likelihood of treating a PPP increased significantly as the number of missions undertaken increased (Fig. 1).

The number of pediatric trauma cases differed with deployment location (Fig. 2). Incidence of PPPs was highest in Afghanistan (AUC at 0.76, IC 95 0.65–0.85, $p = 2.089\text{E}-5$); the Central African Republic and Chad had AUCs of 0.68 and 0.67 (respectively; $p < 0.05$). Mali was not associated with a significantly high risk of PPPs.

Clinical features of PPP

The majority of PPPs were managed at Role 1 NATO Treatment Facilities (67%), in the field (26%) or in the armored ambulance vehicle. PPP injuries were not always warfare-related: explosions accounted for 20% of injuries and ballistic wounds for 17%, but 63% of PPPs were caused more conventionally (e.g., falls or road accidents) and 24% were domestic accidents. The injury profiles of PPPs were: neurological failure (28%), circulatory failure (24%), respiratory failure (23%), massive hemorrhage (19%) and upper airway obstruction (8%).

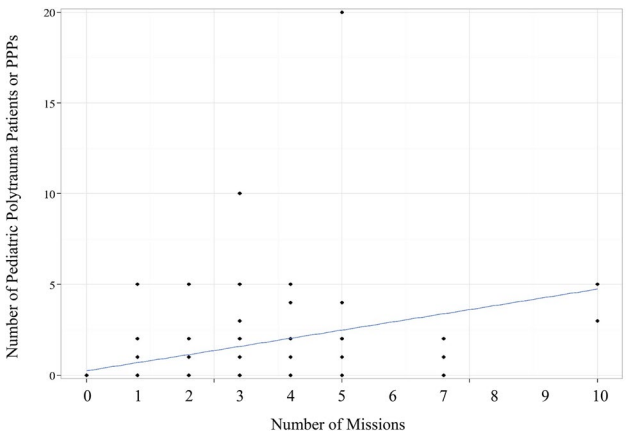

Fig. 1 Graph showing the significant correlation between the number of deployments ["Missions"] undertaken by French military doctors with the number of PPPs treated on each deployment. Spearman's ρ coefficient = 0.4742563; p value = 3.973E − 06

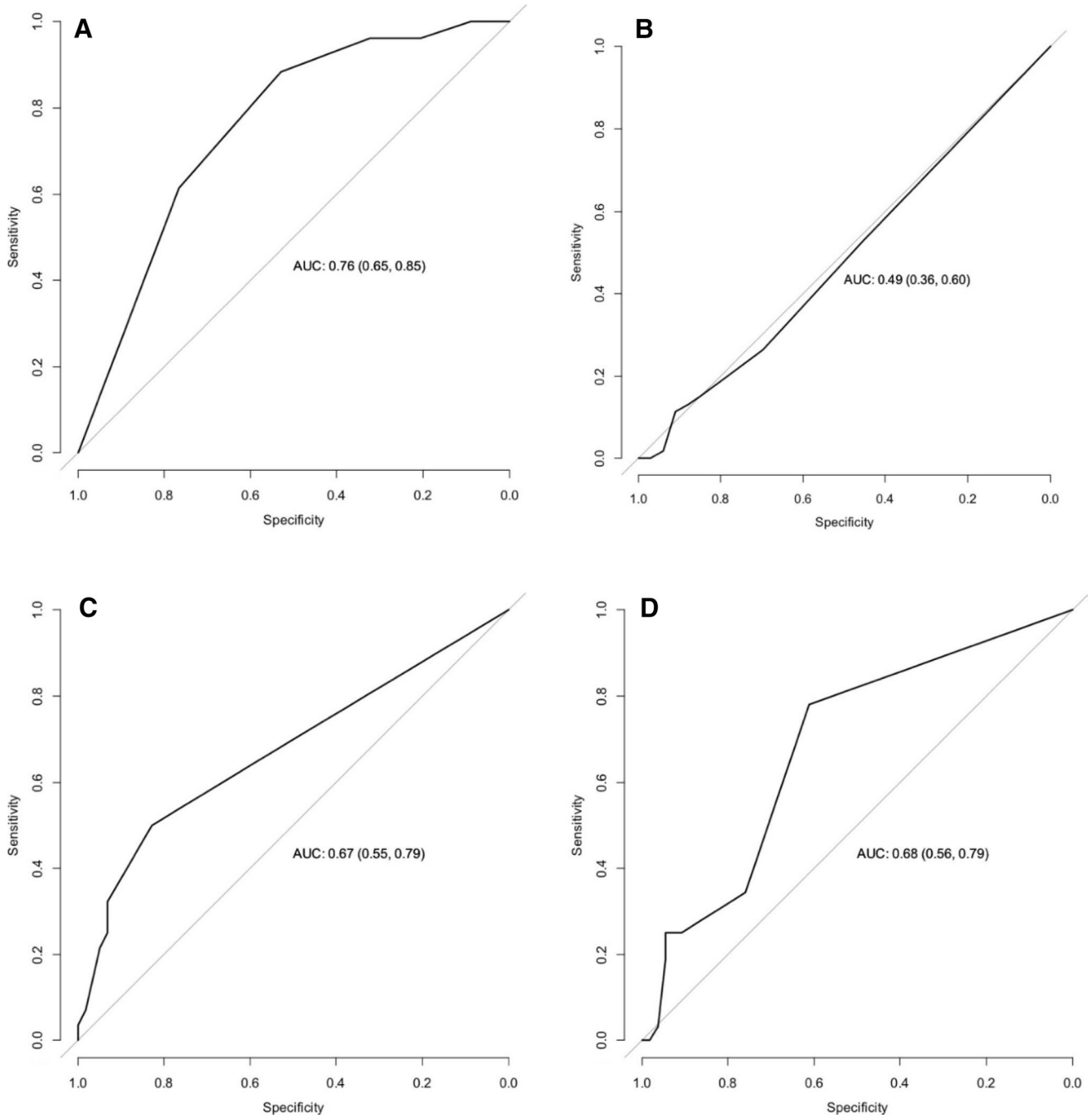

Fig. 2 Four receiver operating characteristic (ROC) curves illustrating the likelihood of a French military doctor having to treat a pediatric polytrauma patient during a deployment in one of the four following countries: **a** Afghanistan (AUC: 0.76, IC95 0.65–0.85, $p = 2.089E-5$); **b** Mali (AUC: 0.49, IC95 0.36–0.60, $p = 0.805$); **c** Chad (AUC: 0.67, IC95 0.55–0.79, $p = 0.005$) and **d** the Central African Republic (AUC: 0.68, IC95 0.56–0.79, $p = 0.002$). AUC = Area under the curve

Pre-hospital management

The management techniques for the PPPs are presented in Table 1. Problems related to the battlefield included: difficulty with care continuity (41%), evacuation difficulties (36%), inadequate equipment (29%), problems in the field (dust, heat, insecurity) (20%), equipment deficiencies (18%) and sheer number of casualties (5%).

Technical issues were also associated with treatment problems and failures. Physicians reported difficulties with

Table 1 Details of the management of pediatric polytrauma patients (PPPs) in French military battlefield pre-hospital settings

Objective	Therapeutic intervention ($n=435$)	
(C) Catastrophic hemorrhage	Compression dressings	20
	Tactical tourniquet	10
	Hemostatic dressings	7
(A) Airways	Spinal immobilization	28
	Oxygen therapy	26
	Opening of the airway	25
	Ventilation	8
	Nasogastric intubation	3
(B) Breathing	Chest intubation	12
(C) Circulation	Intravenous access	40
	Perfusion	31
	Intraosseous	10
	Epinephrine/noradrenaline	7
	Cardiac massage	4
	Cardiac defibrillation	2
(D) Disability	Sedation	23
	Glasgow coma scale	12
	Reheating	11
(E) Exposure	Analgesia	34
	Antibiotic	32
	Monitoring	31
	Burns care	29
	Limb immobilization	22
	Serum or vaccination against tetanus	5
	Urinary catheter	3

Actions are presented in the order of the CABC (catastrophic hemorrhage, airway, breathing, circulation) paradigm of Battlefield Advanced Trauma Life Support

the insertion of peripheral venous ($n=12$) and intraosseous catheters ($n=3$), orotracheal tubes ($n=4$), urinary catheters ($n=1$), nasogastric tubes as well as problems immobilizing limbs ($n=1$). Five physicians also reported iatrogenic accidents.

Physicians' pediatric trauma care competencies

Only 19% of physicians reported feeling "confident" with PPP management; 47% felt they lacked experience when dealing with pediatric trauma. At the beginning of their medical studies, 74% had undertaken a pediatric internship (3 months) and 48% had been on a pediatric emergency internship (47% in emergency departments, 1% in pediatric pre-hospital care units). As residents, 55% had a pediatric internship (6 months) and 60% had been on an emergency internship (59% in the emergency department, $n=1$ in pre-hospital care units).

Continuing education was primarily based in adult emergency units: 74% of physicians graduated with an additional adult trauma qualification, while only 4% graduated with a similar pediatric qualification. Training was available from the French Military Medical Academy in Val-de-Grâce, Paris, France. 57% of doctors were aware of this, but only 10% had participated. Online pediatric e-learning was also available from the FMHS's Remote Education and Information site. 64% of the physicians knew about this, but only 16% had completed it.

Emergency experience in metropolitan France

Experience and military physicians' regular activities in France are illustrated in Fig. 3: 73% of physicians had adult emergency activity, while only 9% was working in pediatric centers. 40% reported family medicine experience, including general pediatrics. The correlation between emergency activity in metropolitan France and feeling "confident" when managing PPP on deployment depended on the type of care required. The results are detailed in Table 2.

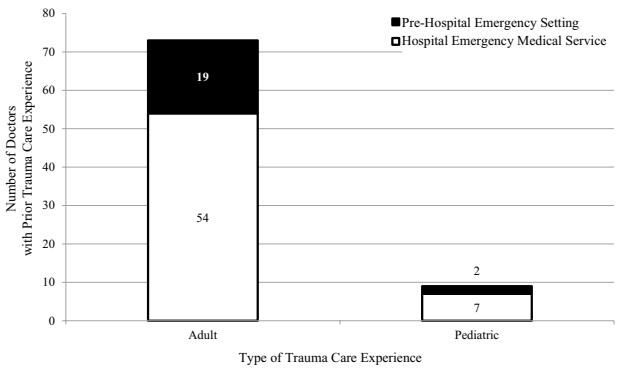

Fig. 3 Graph showing the experience and military physicians' regular emergency activities in metropolitan France. The categories on the x-axis indicate whether the work had been caring for adults or children

Table 2 Table indicating the correlation between current clinical activities in metropolitan France and feeling "confident" when managing PPP on deployment

	OR	CI 95%	*p* value
Adult pre-hospital emergency	3.0	0.6–15.8	0.14
Adult emergency department	1.20	0.3–4.8	1.00
Family medicine	0.72	0.15–3.01	0.75
Pediatric emergency department	NA		
Pediatric pre-hospital emergency	NA		

Discussion

Our result indicated that:

1. Management of PPP on deployment was a rare event; incidence varied with the country.
2. Injury profiles of battlefield PPPs were different to pediatric civilian traumas treated in France.
3. Military physicians reported receiving limited training for dealing with PPPs and that continuing professional education was inadequate. Most reported a lack of confidence when treating PPPs on deployment.
4. Pre-hospital civilian trauma care experience (e.g., adult pre-hospital emergency services) facilitated military PPP management.

This work has highlighted three major issues with current PPP care: (1) constraints due to deployment frameworks, (2) specific PPP care requirements (3) lack of specialist competences.

Deployment constraints

These are the most difficult obstacles to overcome, as they include operational context, practitioner isolation and logistical difficulties. Problems could be limited, however, by setting up tactical "health watch" and early-warning systems to identify risk areas and provide physicians with location-specific training before deployment, since prevalence of PPPs differed between countries.

Limitation of non-medical constraints to PPP management could be achieved by:

- Clarification of the tasks that will fall to the FMHS and rules regarding medical aid for the civilian population before each mission.
- Identification and systematization of PPP evacuation circuits to the most appropriate care structures for each theater of conflict to limit delays that generate stress and consume medical resources (personal and material). Evacuation solutions should use existing civilian structures, humanitarian associations or forces already present (NATO or the UN).
- Establishment of tele-expertise communications with a French pediatric trauma center. This would be indispensable and has already been put forward by David et al. [5].

Specificity of PPP care

Constraints related to PPP care were related to the mechanism and profile of injuries. Described injuries, similar to those described in other war zones [1–3, 6, 8, 9], posed two problems: the first was that the injuries were different from those in metropolitan France where blunt trauma accounted for more than 95% of PPPs [10–12] and 88% of traumatic injuries were brain injuries [11, 12]. In the field, by contrast, hemorrhagic shock and multiple shrapnel wounds were most commonly reported and they tended to be penetrating, lesional injuries like burns and blasts.

The second problem was that the profile of injury of children differed to that of soldiers [13–15] who carried ballistic protection in the majority of cases, limiting damage to their thorax and abdomen. Furthermore, soldiers were attended to within minutes of injury, their management circuit was well-organized and included evacuation to a surgical unit. By contrast, PPP management first required the combat zone to be secured and then for the organization of a medical evacuation not initially intended for civilians. These delays complicated and lengthened the management time, leading to hypothermia, increased blood loss and the consequences of hemorrhagic trauma.

Care of PPPs in the field also presented difficulties due to the complex techniques required to treat burns, the widespread use of compression bandages, hemostatic tourniquets and thoracic drainage. Furthermore, some procedures were adapted from adult protocols, as pediatric parameters were unknown e.g., systematic nasogastric intubation during acute respiratory distress, traumatic cardiac arrest management and the nature and volumes of solutes for fluid therapies. The result was that the application of knowledge acquired in France was limited by the context of the deployment; it was also difficult to transpose adult procedures to the PPPs.

However, despite the differences, PPPs were reported to have a profile of injury quite close to adult war trauma. Ground zero damage control consisting of aggressive prevention of hypothermia, coagulopathy and hemorrhage was applicable [6, 16–18]. Despite the difficulties related to the variety and complexity of PPP care, the number of reported failures remained low. The main failures were centered on three areas: the placement of peripheral venous or intraosseous catheters and orotracheal intubation.

Children weighing less than 30 kg have a low survival rate after traumatic injury [19–21] and their care is particularly complex, and unlike larger children. In France, in the event of an attack involving children, the distribution of PPPs between adult and pediatric trauma centers should be done using this threshold value of 30 kg [22]. We believe that in the field, the number of PPPs weighing less than 30 kg will probably be low, and so the majority could be treated as adults.

Lack of specialist competences

Respondents ascribed their lack of pediatric expertise to inadequate training. Pediatric experience in the second and third years of medical school was limited to pre-hospital settings and beyond registration, continuing education in pediatrics was sporadic. In metropolitan France, most doctors reported doing daily emergency room rounds, but they also said that this work did not provide them with real benefits in terms of increased confidence (Table 2).

Several possibilities exist to improve training: pre-registration, medical students could undertake at least one placement in an emergency or pediatric pre-hospital setting. Post-registration, a supplement about the management of PPP could be added to the "pediatric module" of the existing training provided by the Army Health Service.

At the time of writing, different forms of continuing professional education are available [23, 24], especially via e-learning. Training days are available to maintain pediatric trauma care skills (e.g., by the Parisian Fire Brigade) and short courses in pediatric emergency care, such as the European Pediatric Life Support course, offers 2-day courses. We do not recommend offering this training systematically, however, due to a lack of available time between missions; instead, courses should be offered on a case-by-case basis, depending on deployment location and the particular needs of each doctor.

Conclusion

Pre-hospital management of a PPP by physicians of the FMHS in the field is a rare event, although incidence varies according to the country. Care is complicated by differences between combat and civilian pediatric trauma and our data also revealed logistical constraints linked to hostile battlefield terrain. We found that doctors estimated their initial and continuing training in pediatric traumatology to be insufficient, but that because management of heavier PPPs was quite similar to that of adult trauma patients, it often succeeded despite the many challenges.

This work did have limitations: it was a questionnaire survey that asked for recollections of events, data were from a self-completed questionnaire and answers were reported experiences. Due to the absence of follow-up interviews, data was not independently verified. Regrettably, participation was low (approximately 20% of the target population of 500 military doctors responded) and so we have been conservative with interpretation of the results, especially as analysis was limited by not only the sample size but also a lack of consistency in responses to all questions.

Nevertheless, we believe this work presents a valuable insight into battlefield pediatric trauma management and that conditions for care of PPPs could be improved by risk assessment and organization of appropriate medical support for the theater of conflict for each deployment location in turn. In-service pediatric trauma training for doctors does not have one single solution for all but requires individualization on a case-by-case basis. All task forces of different nations are required to adapt their training to the needs of PPPs.

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Author contributions Literature search: Hornez, Laville. Study design: Hornez, Laville, Mornand. Data collection: Laville. Data analysis: Laville, Hornez, Desterke. Data interpretation: Hornez, Laville, Lebleu. Writing: Laville, Hornez. Critical revision: Lebleu, Aigle, Hornez.

Compliance with ethical standards

Conflict of interest All authors declared that they have no conflict of interest.

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