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Specific stretchers enhance rapid extraction by tactical medical support teams in mass casualty incidents☆

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ABSTRACT

Objective: In mass casualty incidents where the threat is on-going, victim evacuation remains a challenge: fast extraction while respecting spinal immobilisation and haemorrhage control. Different devices can be used but their suitability has not been compared.
Methods: We conducted a simulation study comparing eight extraction devices with a randomisation of the order of testing. Five teams, consisting of four officers, evacuated a single victim in five steps: device's deployment, loading the victim, carrying the victim along a corridor, negotiating a corner passage and a descent by staircase. Primary outcome was the emergency extraction time, from deployment to the first obstacle. Secondary outcomes included ease of transport and victim's stability, rated from 1 (worst) to 10 (best).
Results: One hundred and sixty simulations were carried out. The median emergency extraction time was 16.7 [IQR: 11.6–24.9] seconds. The three speediest devices were the "firefighters' worn", "snogg" and "flexible tarp", taking 9.7 [8.1–11.0], 11.7 [10.9–15.4] and 12.2 [11.2–17.9] seconds respectively ($p < 0.0001$). Regarding the ease of transport, the three best-evaluated devices were the "firefighters' worn", "strap" and "flexible tarp" with 10 [9–10], 9 [8–9] and 8 [8–9] respectively ($p < 0.0001$). Considering stability reported by simulated victims, the three best-evaluated devices were the "inflated stretcher", "flexible tarp" and "firefighters' worn" with 8.0 [7.8–9.0], 8.0[7.0–8.0] and 6.5 [6.0–7.0] respectively.
Conclusion: Devices were not equivalent in terms of extraction time and suitability criteria. For rapid extraction of victims from danger zones, the "firefighter's worn" and "flexible tarp", as very simple stretchers, seem to be the most appropriate devices.

Introduction

The main priority of counter terrorism units and their tactical teams is to neutralize any given threat [1]. Teams include tactical medical physicians to support the mission in case of the need for care under fire [2]. In such cases, a tactical field care zone, within the danger zone, is created [3]. In mass casualty incidents (MCI) under on-going threat, tactical medical physicians organize the casualty flow from the hot (danger) zone to a safe zone without disturbing the police operation [4,5]. This procedure must be as fluid and dynamic as possible [6,7].

Whilst casualty evacuation priorities usually include spinal immobilisation, prevention of hypothermia and haemorrhage control, when a threat remains, emergency extraction aims at a single main objective of escaping from the danger zone. Specific devices are necessary to facilitate this. Several such techniques and devices exist, however their performance has never been compared. The aim of this study is to define the device corresponding to the best tactical effectiveness. The primary outcome measure for extraction from the hot zone is obviously the time delay between the departure of the tactical team and victim arrival at the safety point. Our hypothesis was that all approaches would not be equal, and hope this study will guide tactical units in their choice of stretchers.

Materials and methods

Design

We conducted a simulation study, which compared different extraction devices and techniques with a randomisation of the order of testing. The study was carried out within the medical

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group of the French police task force: Research, assistance, intervention, deterrence (RAID). The protocol was approved by the Human Resources Management Office for the Ministry of Interior Ethics Committee.

Equipment evaluated

We evaluated eight extraction devices (Table 1) which can be broadly categorised into three types: civilian devices including the “snogg”, “immobilisation board” and “firefighters’ worn”; military devices, the “foxtrot” and “net”; and tactical devices including the “flexible tarp”, “inflated stretcher” and “strap”. The “firefighters’ worn” is a technique of transporting a victim rather than a device, however it is referred to as a device hereafter for simplicity. The seven devices studied are illustrated in Fig. 1, as well as the “firefighters’ worn”.

Scenario

The victim was positioned on the floor, in a building, in an urban environment. The evacuation plan was composed of five stages: deployment of the device under test to the field (involving a 20 m run), loading the victim, carrying the victim flat on their back along a 10 m corridor, negotiating a corner passage and then a descent by staircase.

Simulation

Five groups, each composed of four RAID officers, participated in this study. The victim played an injured and disabled RAID officer, in intervention protective clothing. The victim’s weight was about 80 kg. Their equipment consists of a heavy jacket and helmet; weighing about 30 kg. The total weight of the victim was therefore approximately 110 kg.

The evacuation team leader, just prior to each departure for the first stage, was assigned a device for evacuation by an investigator. To limit a learning bias, all officers had been trained to use all of the extraction devices.

An investigator noted the different variables of interest.

Measurements and outcomes

We measured the duration of each stage of the victim’s extraction from the field. Stage times were defined as follows. T1 corresponds to deployment: from the moment of alert to the existence of a casualty until the device was next to the victim and ready to load. T2 corresponds to loading: from the end of T1 until the victim was on the stretcher and the team ready to go. T3 corresponds to the course from the point of injury to the casualty nest: from end of T2 until the victim was moved to the end of the corridor. T4 corresponds to the corner passage: from end of T3 with the victim’s head two meters upstream of the corner until the victim’s feet were two meters downstream of the corner (moving head first). T5 corresponds to the descent of a floor by staircase: from the end of T4 with the victim’s head two meters upstream of the staircase at level N, until the victim’s feet were two meters downstream of the staircase at level N-1.

We defined three time combinations: emergency extraction time (T1+T2+T3), emergency extraction time with an obstacle (T1+T2+T3+T4), and the global extraction time (T1+T2+T3+T4+T5). The primary outcome for this study was the emergency extraction time (seconds), in other words, the time it would take to remove most casualties to a safety zone. Emergency extraction time with an obstacle and global extraction time were evaluated as secondary criteria. We also evaluated other secondary outcomes such as ergonomic and stability criteria. Ease of transport and obstacle crossing capacity were collected from the extraction team. Perceived victim stability (strapping and risk of fall) and comfort were collected from the simulated victim. These subjective data were collected with a numerical scale from 1 (worst) to 10 (best).

In order to compare objectively the devices for use in an MCI situation, we also collected the number of persons required for carrying the loaded device (one to four), the weight of the device, and immobilisation capabilities.

Statistics

For this exploratory analysis, we empirically estimated that we needed 20 evaluations per device. Every group of officers tested each device four times. We randomized the order of passage of the extraction equipment. A randomization list was created with R software (v3.3.3).

Data are expressed as medians with interquartile ranges (IQR). Differences between the eight devices were compared using the Friedman test. The three most efficient devices were compared, two-by-two, using the paired non-parametric Mann–Whitney test. All tests were two-sided. Bonferroni’s adjustment for multiplicity was used to interpret the type 1 error. As we made three comparisons, the significance level was set at 0.017. All analyses were performed using R software (v3.3.3).

Results

One hundred and sixty simulations were carried out. Physical characteristics, including weight of the devices, are presented in Table 1. The numbers of operators needed for each stage using each device are presented in Table 2.

General results

The whole extraction took on average 45.6 [IQR 35.6–56.6] seconds. Different median times for deployment, loading, course, corner passage and staircase were respectively 3.0 [1.6–5.8], 5.8 [3.2–8.1], 6.6 [5.9–8.0], 8.4 [6.8–11.4] and 16.8 [13.3–19.4] seconds. The emergency extraction took on average 16.7 [11.6–24.9] seconds and the emergency extraction with an obstacle 26.3 [19.4–35.3]

Table 1
Device characteristics.

	Weight	Transportable in the primary response bag	Immobilisation straps (number)	Cervical and head immobilisation	Suitable for hoisting	Floatable on water
Snogg	4,5Kg	No	0	No	No	No
Flexible tarp	< 1Kg	Yes	1	No	No	No
Strap	< 1kg	Yes	0	No	No	No
Firefighters’ worn	0Kg	Yes	0	No	No	No
Immobilisation board	6 Kg	No	3	Yes	No	No
Inflated stretcher	4,5 Kg	No	3	Yes	Yes	Yes
Net	< 1Kg	Yes	0	No	No	No
Foxtrot	5,5Kg	No	2	No	No	No

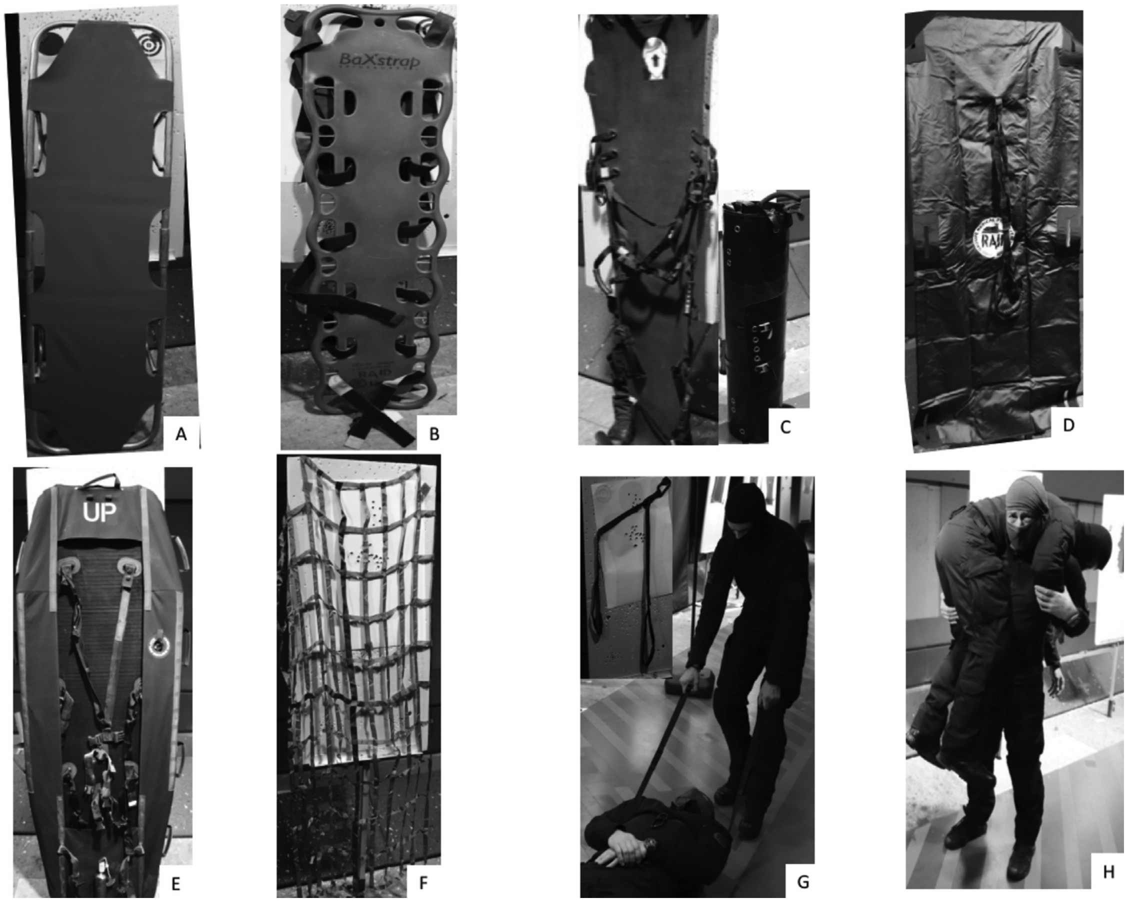

Fig. 1. Illustration of each device.
Legend: A: snogg, B: immobilisation board, C: foxtrot, D: flexible tarp, E: inflated stretcher, F: net, G: strap, F: Firefighter's worn.

Table 2
Minimum number of operators required by device for each evacuation step.

	Deployment	Loading	Course	Corner passage	Staircase
Snogg	1	2	2	3	4
Flexible Tarp	1	2	1	1	4
Strap	1	2	1	2	3
Firefighters' worn	2	2	2	2	3
Immobilisation board	1	2	2	3	4
Inflated stretcher	1	2	2	3	4
Net	1	2	3	3	4
Foxtrot	1	2	2	4	4

seconds. Operators evaluated the ease of transport across all devices to be 8 [4–9] and the crossing capacity 5 [3–7]. Simulated victims reported stability at 6 [4–7] and comfort at 5 [4–7] on average.

Times

Distributions of the global extraction time, the emergency extraction time and the emergency extraction time with obstacle, for each device, are presented in Fig. 2. Distributions of each stage are presented in the appendix.

The emergency extraction times were generally different (Friedman test: $p < 0.0001$). The three speediest were "firefighters' worn", "snogg" and "flexible tarp", taking a median 9.7 [8.1–11.0], 11.7 [10.9–15.4] and 12.2 [11.2–17.9] seconds respectively. Significant differences in speed were observed between the "firefighters' worn" and "flexible tarp" ($p = 0.0002$) and between "firefighters' worn" and "snog" ($p < 0.0001$). No difference was observed between "flexible tarp" and "snog" ($p = 0.7$). The global extraction times were also grossly different (Friedman test: $p < 0.0001$). The three speediest were "firefighters' worn", "flexible tarp" and "snogg" with 32.0 [28.5–37.4], 35.1 [29.6–44.5] and 42.5 [34.2–50.6] seconds respectively. Significant differences were observed between the "firefighters' worn" and "snogg" ($p = 0.003$). No difference was observed between "flexible tarp" and "firefighters' worn" ($p = 0.08$) and between "flexible tarp" and "snog" ($p = 0.3$). The emergency extraction times with an obstacle are also globally different ($p < 0.0001$). The three speediest were the "firefighters' worn", "flexible tarp" and "strap" with 16.5 [14.9–20.9], 18.5 [17.5–26.18] and 21.5 [18.35–26.6] seconds respectively. The "firefighters' worn" was significantly faster than both the "flexible tarp" ($p = 0.007$) and the "strap" ($p = 0.002$). No difference was observed between the "flexible tarp" and "strap" ($p = 0.2$).

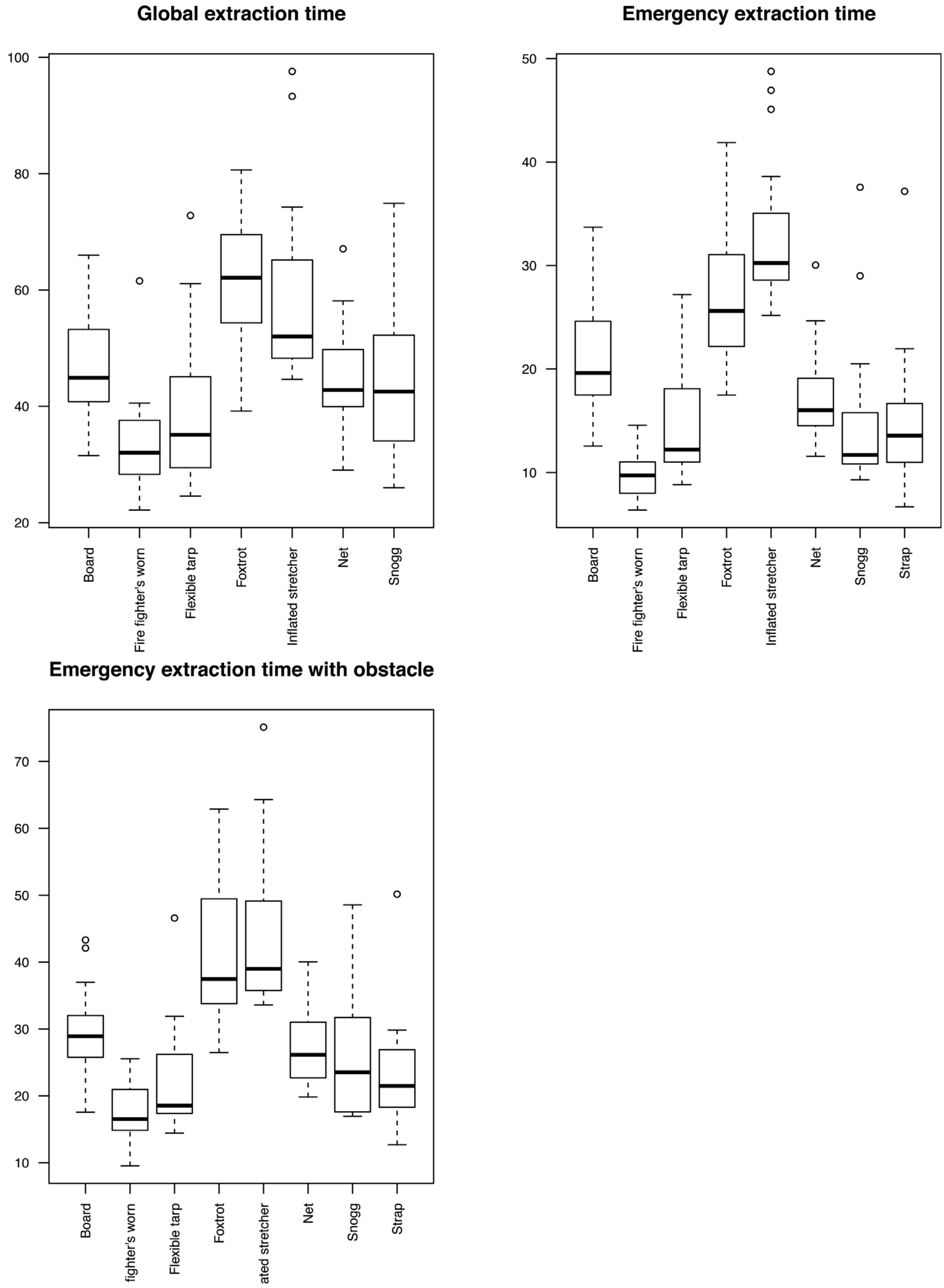

Fig. 2. Distribution of evacuation times (Emergency extraction time, Emergency extraction time with obstacle, and Global extraction time) for each device. Legend: The data is missing for the "strap" for the global extraction time due to the impossibility to use the strap on the stairs.

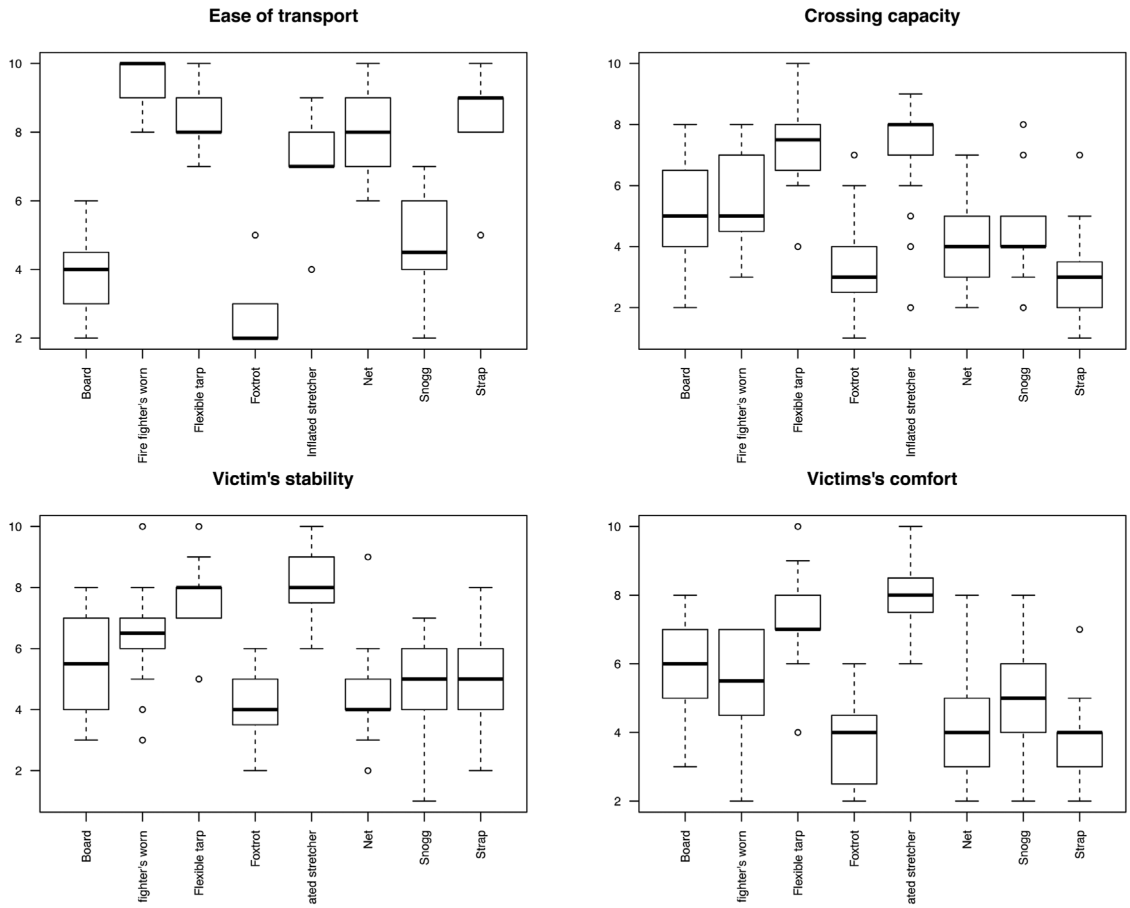

Fig. 3. Distribution of ease of transport, crossing capacity, victim stability and victim comfort for each extraction device.

Capabilities

Distributions of the ease of transport, the obstacle crossing capacity, the victim's stability and the victim's comfort, for each extraction device, are presented in Fig. 3.

The ease of transport was grossly different across devices ($p < 0.0001$). The three best-evaluated devices were the "firefighters' worn", "strap" and "flexible tarp" with scores of 10 [9–10], 9 [8–9] and 8 [8–9] respectively. Scores for the "firefighters' worn" were significantly better than for the "strap" ($p = 0.001$) and the "flexible tarp" ($p = 0.003$). No difference was observed between "flexible tarp" and "strap" ($p = 0.33$).

The obstacle crossing capacity was also different ($p < 0.0001$). The three best-evaluated devices were the "inflated stretcher", "flexible tarp" and "firefighters' worn" with 8.0 [7.0–8.0], 7.5 [6.8–8.0] and 5.0 [4.8–7.0] respectively. Significant differences were observed between the "firefighters' worn" and "inflated stretcher" ($p = 0.01$) and between "firefighters' worn" and "flexible tarp" ($p = 0.001$). No significant difference was observed between the better scoring "flexible tarp" and "inflated stretcher" ($p = 0.85$).

The perceived stability also varied across devices ($p < 0.0001$). The three best-evaluated devices were the "inflated stretcher", "flexible tarp" and "firefighters' worn" with 8.0 [7.8–9.0], 8.0 [7.0–8.0] and 6.5 [6.0–7.0] respectively. The "inflated stretcher" and "flexible tarp" were both found to be significantly more stable than the "firefighters' worn" ($p = 0.002$ and $p = 0.006$ respectively). No significant difference was observed between the "flexible tarp" and "inflated stretcher" ($p = 0.19$).

The devices also received varying comfort scores ($p < 0.0001$). The three best-evaluated devices were the "inflated stretcher", "flexible tarp" and "immobilisation board" with 8.0 [7.8–8.3], 7.0 [7.0–8.0] and 6.0 [5.0–7.0] respectively. The "inflated stretcher" and "flexible tarp" were both found to be significantly more comfortable than the "immobilisation board" ($p = 0.001$ and $p = 0.006$ respectively). No significant difference was observed between the "flexible tarp" and "inflated stretcher" ($p = 0.17$).

Discussion

The "firefighters' worn" was the fastest method for extraction. Other devices obtained better results in terms of stability and comfort however. The "flexible tarp" could be a good compromise between speed and stability.

As the Committee for Tactical Emergency Casualty Care guidelines for civilian mass casualties' make clear, Tactical Emergency Medical Support (TEMS) procedures require very specific materials, techniques and training [8,9]. To remove injured victims in particular from on-going threats requires an appropriate stretcher. The Hartford consensus surmises that TEMS teams must remove victims from the threat before providing life saving interventions [10,11]. This principle is why the main outcome of our study was the emergency extraction time.

We found the "firefighters' worn" was the fastest for all three evaluated times. The technique had the advantage particularly on the two first steps: deployment and loading (appendix), probably because there is no actual device required. The deployment and loading times are very quick as compared to any other stretcher techniques. Regarding the global extraction time, “flexible tarp” and “firefighters’ worn” were similar. The “flexible tarp” made up for lost time in the first two stages by allowing rapid negotiation of obstacles. The ten-meter course that was used to evaluate the emergency extraction time is obviously a short distance. This is because the meta-analysis by Turner et al. of MCIs found that the most common “escape route” to the casualty safe zone was a simple leap [12]. The scenario for our study was designed to reflect this small but vital leap. Anyway, time couldn’t be the only criterion to consider in this traumatized population.

Immobilisation of trauma patients is important in order to avoid exacerbation of injuries and secondary injury, and as part of haemorrhage control [13]. In our study, three stages put immobilisation to the test, namely the loading, corner passage and descent by staircase stages. Regarding obstacle crossing capacity, stability and comfort, the “inflated stretcher” and “flexible tarp” both rated better than the “firefighter’s worn”. It is necessary to remember however that spinal immobilisation, and fitting of cervical collars for example, though important, cannot be allowed to impact on extraction time in this context [14,15]. In the “care under fire zone”, fast extraction can justify a lack of conformity with standard patient packaging, with full immobilisation taking place instead in the relative safety of the casualty collection point [16]. The quest for the optimal device should be a compromise between speed and these other capabilities.

In addition to the criteria already discussed, the cost in terms of manpower must also be considered. In MCIs, an efficient casualty flow will depend on this crucial question. Looking at the lessons learned from the Bataclan mass murder [6], a useful tactical stretcher should require a maximum of two carriers. The “flexible tarp”, “strap” and “firefighter’s worn” seem to be the most appropriate in this respect (Table 2).

Finding a specific device that meets the criteria investigated by this study i.e. simple to use and easy to deploy, with very quick extraction and good immobilisation of the casualty, should be a priority for Special Forces units. In this study, two devices stand out from the others as good candidates: the “flexible tarp” and the “firefighter’s worn”. They both ranked in the best three for the majority of outcomes. The advantage of “firefighter’s worn” is reduced however if we look at the utilization of team members and their physical energy, particularly with regards to deployment. We believe that the “flexible tarp” therefore would be the best device for evacuation.

A limitation of this study is the focus on the simulation of a MCI with TEMS in the hot zone. Results cannot be generalized to Emergency Medical Service (EMS) teams or for management of a single patient. In MCIs, the objective of all Police and Special Forces units is to stop the threat and simultaneously extract all casualties to a safety zone. This corresponds to the “stop the killing and then stop the bleeding” program [17]. After a safe extraction, EMS teams will be able to take over medical and paramedical evacuation to the hospital care structure. Furthermore, the experience and training of the teams involved in this study meant that they were able to deploy all devices effectively. In other hands this may not be so easy, and training requirements for each of the devices might be a fruitful area of further study.

A simple process with simple techniques is essential for optimal efficiency during chaotic times. Success in this field, in line with the same principles, has already been achieved by the widespread deployment of specifically designed tactical tourniquets in such incidents [18,19]. Appropriately adapted devices allow a small number of operatives to achieve a lot, and well-selected stretchers should facilitate fast, uncomplicated extraction in keeping with tactical objectives.

Conclusions

In moving towards better understanding, this study shows that the “firefighters’ worn” and “flexible tarp” are the most efficient options for use in the hot zone. Other stretchers would be a second choice for deployment to the medevac zone. Many stretchers for technical medevac with good immobilisation specifications are more useful for military overseas operations than for mass casualty events in urban environments. In this case, the speed of the first escape noria is key and tactical stretchers must be adapted to these constraints.

Author contribution

RAID: study design, data extraction, data interpretation and preparation of the manuscript;

Paul-Georges Reuter: study design, data analysis, data interpretation and preparation of the manuscript; Chloe Baker: preparation of the manuscript; Thomas Loeb: study design, data interpretation, preparation of the manuscript and critical revision. All authors approved the final version of the manuscript.

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Conflicts of interest

None declared.

Conflicts of interest statement

Authors have no conflicts of interest to declare regarding the submitted work.

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Appendix A. Supplementary data

Supplementary material related to this article can be found, in the online version, at doi:https://doi.org/10.1016/j.injury.2018.12.012.

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