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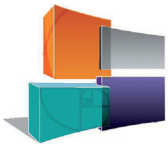

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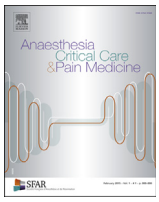

Review

Evolution and organisation of trauma systems

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ABSTRACT

Over the last 20 years, numerous studies have fairly consistently reported an improvement in the prognosis of patients with severe trauma after the establishment of a trauma network. These systems can be either exclusive, in which all patients are referred only to a small number of specifically designated centres that meet strict criteria, or inclusive, in which patients may be referred to any hospital of a particular area according to capacity, which is observed in France. Hospitals are classified (level 1 to level 3) according to their technical facilities and the number of patients admitted for severe trauma, knowing that studies have also shown an improvement of the outcome for the most severely injured patients (haemorrhagic shock, severe head trauma), in hospitals with the greatest technical facilities and the most important activity. The triage of the patients to a suitable centre must be done after careful prehospital evaluation, which is made on clinical criteria (mechanism, injury, medical history), measurement of vital signs, calculation of scores (RTS, MGAP) or based on classifications. According to this assessment, the patients will then be triaged to a centre that has the capacity for the optimal and definitive management of these injuries. The goal is then to avoid under triage which is synonymous of retransfer, loss of time, and probably also prognosis worsening, and to avoid over triage that may induce an inadequate use of resources, activity overload and cost increase. Thus, it seems essential to develop trauma networks to improve mortality and morbidity of patients that undergone a severe injury. These trauma networks will then have to be evaluated and a register set up.

1. Introduction

Serious injury is the leading cause of death in the world and it is associated with a significant human and social burden in terms of disability, cost and loss of productivity [1,2]. The prevention of trauma and the organisation of trauma care is a real challenge for our societies, as it impacts prognosis. Severe injury appears (or should appear) as a real public health problem that remains sensitive to different level of prevention measures including primary (prevention of the event), secondary (reduction of injury severity(s) resulting from the event) or tertiary prevention (optimisation of the outcome associated to the event from its occurrence) [2].

A trauma system is structured around prehospital initial management and triage, as well as in-hospital care and rehabilitation, which are associated with teaching and research, within a defined geographic area integrated in a regional public health system [2]. It has been shown since decade that the implementation of trauma systems is effective in many parts of the world, particularly in North America, but also in other countries such as Germany, Australia, Holland and Israel [3–8]. In France, development of networks began approximately ten years ago in the Rhône-Alpes region with the networks "SOS-Trauma" from RESUVAL

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(''Réseau des Urgences de la Vallée du Rhône''), the Trauma System from the RENAU (''Réseau Nord Alpin des Urgences'') and more recently the Trauma Base [9,10].

The objective of this review is to describe the different models of existing trauma networks and to discuss their effects on the improvement of the outcome.

2. Developpement of trauma system

The development and implementation of trauma systems has been directly influenced by experiences related to the different conflicts around the world (for instance, 1st and 2nd World War, Korean and Vietnam Wars) during which, one of the main lessons learnt was that prompt evacuation, early resuscitation and referral to an experienced surgical centre reduced mortality [11]. As early as 1922, the American College of Surgeons recognised the need for a systematic approach to trauma and formed the Committee on Treatment of Fractures, which later became the Committee on Trauma. The establishment of regional trauma networks in North America was also under strong public pressure for a more organised and systematic approach to the management of severe trauma after the publication of several articles that suggested that delayed or inadequate care could have resulted in several preventable deaths [12]. In conjunction, the National Council of Research (US) published in 1966 a report entitled ''Accidental Death and Disability: The Neglected Disease of Modern Society'', which supported a reorganisation of trauma care [13]. Between the late 1970s and the early 2000s a ''trauma system'' was implemented in every US state. In 2002, 35 states had a formalised organisation with 1154 adult ''trauma centres'' [14]. In 2000, according to the American Hospital Association, 258 hospitals reported that they had one and that number increased to 387 (2010) and 416 (2013) [15].

2.1. Development of system according to the region of the world

According to the regions, the development and organisation of trauma systems may have been carried out in different ways depending to socioeconomic and geographical characteristics, medical organisation and epidemiology of trauma. For example, differences exist between the French and US trauma systems, which have independently evolved over the past several decades [1,16]. Penetrating trauma are more often observed in US than in French trauma centres where it represents usually less than 15% of the injury [10,17,18]. However, the most commonly discussed differences have to do with prehospital care; in France, this is performed by a physician-led team that initiates resuscitation at the injury scene and continues this during transport. In the United States, non-physician first responders (''paramedics'') constitute the emergency response. Fewer interventions are performed, with first responders aiming to transfer the patient to definitive care immediately. Significant national differences in the organisation of in-hospital care and initial trauma resuscitation exist as well. In the United States, emergency physicians and trauma surgeons provide the initial care for the severely injured, with the surgeon typically directing the team and assuming responsibility of the patient. In France, an anaesthetist–intensivist leads the trauma team, receives the patient in the trauma bay and assumes responsibility of resuscitation, deciding with surgeons the best diagnostic and therapeutic strategy. When both systems have been compared, it has been shown that patients admitted to a French trauma centre had an equal chance of survival compared with similarly injured patients treated at US trauma centres [19].

2.2. Effects of the implementation of a trauma system

Numerous studies around the world have reported that the implementation of a system for the management of severe trauma patients is accompanied by an improvement in their vital or functional prognosis [4,5,7,8,20]. This improvement has been observed in North America but also in other countries (Israel, the Netherlands etc.) [7,8]. In a meta-analysis published in 2006 and which included 14 studies, a benefit for the establishment of a trauma systems was found in 8 studies and overall implementation of such system was associated with a 15% mortality decrease [4]. Similar or superior results have been also found in other studies [21,22]. Tinkoff et al. described a decrease of more than 25% in mortality [23]. In the Netherlands, Twijnstra et al. also observed a significant improvement in survival (OR: 0.89, 95% confidence interval: 0.80–0.98) [7].

However, it should be noted that the main benefits for the implementation of a trauma system was mainly observed for the most severely injured patients (Abbreviated Injury Scale [AIS] ≥ 4 or Injury Severity Score [ISS] > 15), those who were in shock, the older and in a recent description, for those that needed a laparotomy [24–27]. Interestingly, it has also been reported that implementing a trauma system not only improves patient prognosis but also reduces costs [28]. Similar results were observed for patients in need of emergency surgery in another work, and it was suggested that this benefit was mainly related to the high skill level at the receiving hospital and not only the initial evaluation or the surgical [29]. Lastly, it should be noted that the benefit of the implementation of a trauma system is mainly observed after a decade of practice [30].

3. Organisation of a trauma system

Two forms of trauma system have been developed. The first one is named ''exclusive'' whereas the second one, that has been developed since 1991, is named ''inclusive'' [2].

3.1. Exclusive system

In this system, essentially observed in the US, patients are referred to a low number of very specialised and designated hospitals, the so-called ''Trauma Center'' [2]. An exclusive system functions as a funnel, not a network, and it does not use, let alone maximise, the resources of other health-care facilities within the region [2]. The main disadvantage of this system is that it leads to attenuation of skills in non-designated centres, with resultant loss of experience and surge capacity. Another disadvantage is the theoretical risk of having a volume of patients that overwhelms the capacity of the few available trauma centres. However, with the introduction of such a system, the relative risk of death has been reduced by 20% as compared with patients admitted to non-specialised centres [23]. In support of this principle, a number of studies have reported that patient survival is better in the centres receiving the most patients, especially for the most severely injured (haemorrhagic shock, severe traumatic brain injury) [23–25]. However, it should be mentioned that, although the exclusive model works well in urban and suburban settings where there are enough trauma centres to provide access and to care for the expected number of injuries, in rural areas and areas with limited resources, transport times to the trauma centre may be very long, especially in periods of inclement weather when aeromedical transport cannot be used. Moreover, the number and length of inter-facility transfers may place a severe burden on EMS resources. These limitations led to the development of the ''inclusive'' system in the early 90s.

3.2. Inclusive model

In this model, all health-care facilities within a region are involved in the care of injured patients according to their capabilities and resources [2]. The objectives of such a system are to optimise the resources of the hospitals, to adapt the level of care required by the patient at the receiving centre, to avoid saturation of the referral centres by patients with minor injuries, in the event of multiple casualties, to be able to have a sufficient number of hospital to take care of the injured patients and to avoid too long transport times. Ideally through a regional medical dispatch that interacts with EMS, the system functions to efficiently match an individual patient's needs with the most appropriate facility, based on abilities, resources and proximity. The objective is to refer to the high-level trauma centre the most severely injured patients whereas less injured patients may be optimally managed in local hospitals [31].

With the introduction of this type of system, an even greater positive effect on the prognosis of patients was observed as compared to the "exclusive" system. In a study published in 2006, Utter et al. compared the prognosis of traumatised patients admitted to US states where 3 systems coexisted: "exclusive", more "inclusive" or mostly "inclusive"; it was in the latter system that the prognosis was the best [32]. In the Netherlands, where this type of system has been in operation for several years, 78% of severely traumatised patients are admitted to referral centres [33]. Nevertheless, in order to function optimally such a system requires [2,34]:

- the classification of the different hospitals according to the available resource (from level 1 (the highest level) to level 3; (Table 1);
- the definition of effective prehospital triage rules (Table 2);
- transport capacity (land vehicle, helicopter with day/night capacity);
- capacity for the transmission of medical information or imaging to develop multidisciplinary teleconsultation to therapeutic or diagnostic advice, or even to the transfer of the patient to an expert centre.

A benefit of such an organisation has been shown in France on triage and patient prognosis [10,35].

3.3. Hospital classification

It is proposed by North American authors to classify hospitals from level 1 to level 4, where level 1 is the centre that combines all the skills necessary to manage the most severely injured patients, regardless of the nature of injury and/or age of the patient (www.amtrauma.org) [2]. This definition of level-1 trauma centres is also accompanied by the obligation to take care of a certain number of patients with severe injuries (> 240 patients with an injury severity score, ISS > 15) but also to carry out teaching and research activities [1]. In the USA, the implementation of a state-wide "trauma system" requires the application of certification procedures and the monitoring of certain obligations [2]. In addition, since the late 1980s, national standards and the Trauma Center Verification program of the American College of Surgeons (ACS) Committee on Trauma have been implanted [36]. It has been reported that ACS verification when compared to state designation only, appears to be beneficial for outcomes in trauma patients [37].

In France, adaptations to the definition of trauma centres have been proposed by experts (anaesthesiologist-intensivist, emergency physician) in the Auvergne-Rhône-Alpes area (RESUVAL-TRENAU system) and consist of the classification of the hospitals into 3 levels (Table 1), plus an "unclassified" category, which includes hospitals that do not usually receive severe trauma patients, which is the case for most private hospitals and some small public hospitals. In this classification, as in the North American system, hospital categorisation is based on the resources developed by a hospital and the number of patients cared for severe injuries in this hospital. In the Rhône-Alpes experience, the level of the hospital is currently only declarative without any control process and patients are triaged according to prehospital

Table 1
Classification of trauma centers into 3 levels used in France (Auvergne-Rhone-Alpes area). Adapted from www.resuval.fr and www.renau.org.

	Trauma centre Level 1	Trauma centre Level 2	Trauma centre Level 3
Admission Unit	TRU	TRU/ED	ED
Trauma Team	Yes	Yes	No
Critical Care	ICU	ICU	ICU or SDU
Specialised ICU	Yes	No	No
Operating Room H24	Yes	Yes	Yes
Anaesthetist-Intensivist H24	Yes	Yes	On call
General Surgery H24	Yes	Yes	On call
Orthopaedic Surgery H24	Yes	On call	On call
Neurosurgery	Yes	No	No
Cardiac Surgery	On call	No	No
Thoracic/Vascular Surgery	On call	On call	No
Ophthalmic/ENT	On call	On call	On call
Maxillofacial	On call	On call	No
Urology	On call	On call	On call
Gynaecology/Obstetric H24	Yes	On call	On call
Imaging within 30 min	CT/MRI	CT/MRI	CT
AE within 30 min	Yes	Yes	No
Massive Transfusion	Yes	Yes	No
Mobile ICU Ambulance	> 2	At least 2	1
EMS Helicopter	> 1	1	No
Helipad Access	Yes	Yes	Yes
Major trauma (ISS > 15)	> 100	> 50	–
Trauma Research/Education	Yes	No	No

ICU: intensive care unit; SDU: step-down unit; Specialized ICU: burn-ICU, neuro-ICU, paediatric ICU; ISS: injury severity score; EMS: emergency medical system; AE: angioembolisation; TRU: trauma resuscitation unit; ED: emergency department; CT: computed tomography; MRI: magnetic resonance imaging.

Table 2
Grading scale for on scene evaluation and triage of trauma victims used in France (Auvergne-Rhone-Alpes area). Adapted from www.resuval.fr and www.renau.org.

Grade A	Non-stabilised vital distress despite resuscitation
	SBP < 90 mmHg despite fluid loading > 1500 mL and/or vasopressor
	$SpO_2 \leq 94\%$ despite O_2 therapy
	GCS ≤ 8 or motor GSC ≤ 4
Grade B	Stabilisation after Prehospital Resuscitation/anatomic criteria
	SBP > 90 mmHg after resuscitation
	$SpO_2 > 94\%$ with O_2 therapy
	GCS 9-13
	Spinal cord injury with paraplegia/tetraplegia
	Positive FAST
	Severe pelvic injury (open, displaced etc.)
	Severe limb injury with haemorrhage, ischemia or the need for a tourniquet
Grade C	Normal vital sign and high-kinetic criteria and/or medical history
	High-kinetic: fall from more than 6 m; ejected/projected/blasted; death in the same vehicle
	Penetrating injury to head/neck/trunk
	Open fracture femur/humerus
	Fracture of more than 2 segments of long bone
	Insufficient analgesia despite morphine
Consider triage to trauma centre if	
	Pregnancy
	Treatment with anticoagulant agent
	≤ 5 yrs or > 65 yrs
	Severe comorbidity

SBP: systolic blood pressure; GCS: Glasgow coma scale.

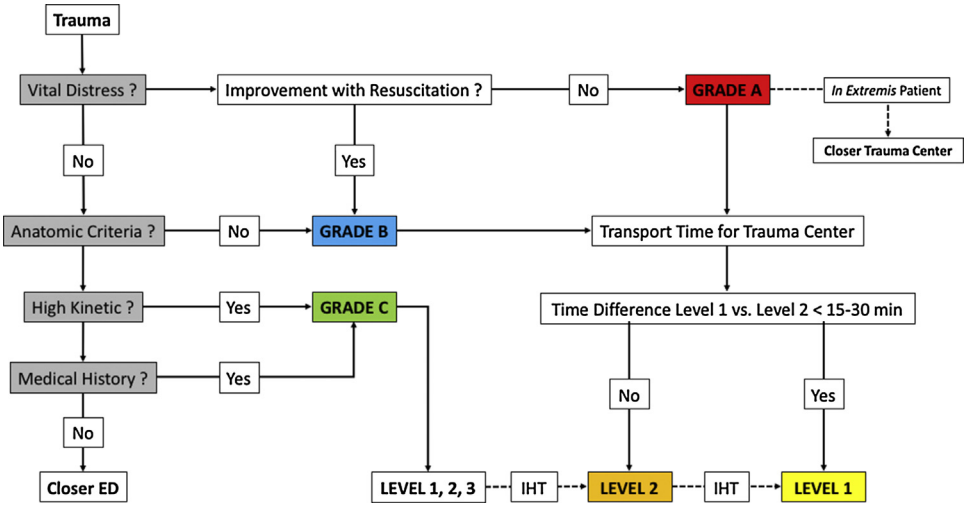

Fig. 1. Algorithm for triage according to the prehospital grade of injury severity and hospital classification. ED: emergency department; IHT: inter-hospital transfer.

evaluation performed by a physician, the advice of medical dispatch from the SAMU (Service d'Aide Medical Urgente) system and a triage algorithm that was implemented a few years ago (Fig. 1).

3.4. Outcome according to the hospital level

It has been found that when the outcome is compared between trauma centres (level 1 versus level 2), after adjustment on injury severity, there is a benefit in terms of survival and functional prognosis in favour of level-1 centres and this benefit is mainly observed for the most seriously injured patients [38]. Demetriades et al., on a cohort of 130154 severely injured patients (ISS > 15), from 256 trauma centres, found a higher mortality rate in level-2 centres (odds ratio: 1.14; 95% confidence interval: 1.09–1.20) [24]. A greater experience of the teams in level-1 trauma centres may explain a great part of this result; a hypothesis that is supported by a strong relationship between the volume of patients and the prognosis, as reported by Nathens et al., in 2001 who found that a threshold of 650 patients per year was associated with better prognosis [25].

4. Prehospital care and triage

4.1. Prehospital Care

Prehospital cares are organised in 2 completely different ways across the world [1,39]. In one system, which relies on emergency medical technicians capable of providing basic life support (BLS) and sometimes advanced life support (ALS), the aim is to limit as much as possible the time spent on the scene by reducing the number of procedures performed to a strict minimum, including the installation of immobilisation devices, oxygen and sometimes venous access. This is the so-called "scoop and run" strategy, which was developed in the US more than fifty years ago [1].

In the second system, which is largely developed in Europe, the prehospital system is based on highly trained paramedics or doctors (Anaesthesiologist-intensivist or emergency physicians) [16,40]. In this system, it is possible to deliver care en route, including advances airway, chest decompression, IV administration of fluids and drugs, including induction and maintenance of general anaesthesia [41,42]. The goal is here to initiate adequate treatment for vital distress but also, after careful evaluation of the injury, to triage the patients to the more suitable hospital. It should be note that in an observational study including patients with severe TBI, prehospital management by doctors rather than paramedics was associated with fewer secondary referrals to major trauma centres [43]. It has been also demonstrated that the presence of prehospital doctors, compared with paramedics, is associated with higher rate of successful intubation, better analgesia and overall, higher rate of invasive procedures without an increase of the time spent on the scene [44,45]. Another advantage of having a doctor in the prehospital ambulance is also the possibility to decide the medical strategy (swift transport versus advanced care) according to the nature of injury and vital distress, the environment (urban versus rural) and finally the mode of transport (helicopter versus ground ambulance).

However, there is still insufficient evidence to conclude that prehospital management by doctors improves outcomes in patients with major trauma [46].

4.2. Prehospital triage

Triaging patients to a facility without the experience and/or capacity to manage injuries (such as angioembolisation, thoracic surgery etc.) may be responsible for a worsening of the prognosis [47–49]. The difficulty in the prehospital arena is therefore to weigh the benefit-risk ratio between going to a hospital located more closely to achieve a rapid haemostasis versus going to the reference trauma centre which may lengthen the transport time. For example, in our region (Auvergne-Rhône-Alpes, France), we have chosen a 15 minute threshold for patients to be addressed to the proximity centre (www.resuval.fr). It should nevertheless be stressed that the decision to go to the local hospital to make a brief "haemostasis stopover" must take into account the training of local anaesthetists-intensivists and surgeons. If properly trained, this alternative would not cause any impairment of the outcome for the patient [50].

Ideally, patients should be triaged according to pre-established protocols (Fig. 1) that take into account the circumstances of the trauma (accident kinetics, height of fall, etc.), injury severity and their topography, vital signs (Glasgow Coma Scale [GCS], systolic blood pressure [SBP], shock index, SpO_2 etc.), the characteristics of the patients in whom these injuries occur (age, medical history, medication etc.) but also the evacuation times and means of transport (road, helicopter-borne) to the trauma centres [9,10,51].

4.3. Direct transport to level 1 trauma centres versus transfer to lower level facilities

It has been reported that triaging a patient to an unsuitable hospital (under triage) is associated with a loss of several hours

(mean 162 min) [52] and ultimately, a worsening of the prognosis [49]. This is illustrated in a study that considered a population of injured patients in a rural area and compared the prognosis between patients referred directly ($n = 1398$) to a level-1 centre to those referred after retransfer ($n = 600$) and found that the mortality at 15 days of patients in the retransfer group was almost 3 times higher than those of patients directly admitted [47]. This increase in mortality, by a factor 3.8, in non-expert centres was also found in the study of Nirula et al. The authors reported that when patients were directed to a non-specialised hospital, the volumes of crystalloid and transfused blood products were much greater (60%) than when they were admitted directly to a level-1 centre (5%) [48]. In another study, it was also found that performing a full body CT-scan in a non-trauma centre did not improve the outcome but was responsible for a 90-minute increase in the length of stay before retransfer [53]. In Quebec, significant work was done more than 20 years ago that resulted in a significant decrease in unnecessary "retransfers" and in mortality of severe traumatised patients (52% in 1992 vs. 9% in 2002) [54]. In this experiment, for the authors, improved prognosis was the result of a combination of multiple elements, two of which are particularly associated with a reduction in mortality: improving the performance of caregivers and implementing prehospital referral protocols [49,55].

Recently, predictive factors for under triage have been described as including the presence of isolated head or pelvic trauma, the occurrence of trauma at night and an age range of 45–54 years [56]. It is suggested that under triage can be reduced using simple score (RTS, MGAP) or classification (Table 2) [10].

4.4. Triage scores

4.4.1. Revised Trauma Score (RTS)

The Revised Trauma Score was developed in the 1970s and includes respiratory rhythm, SBP and GCS. Although it has a good correlation with the prognosis, it requires a calculation table because coefficients are applied to the physiological variables [57]. As a result, a simplified version was developed (T-RTS).

4.4.2. Prehospital Index (PHI)

The PHI is a score developed in Quebec that combines the type of trauma (penetrating or blunt) and vital signs (heart and respiratory rate, SBP, level of consciousness) [58]. For triage, it is often combined with the characteristics of the accident (presence of high velocity criteria such as presumed velocity of vehicle crash etc.) and the judgment of the ambulance attendant [59]. However, while it can predict the presence of severe injuries, its use is associated with significant over triage [59].

4.4.3. MGAP Score

The MGAP score has been recently validated by a French multicentre study that takes into account age (> 60 years old), the nature of the trauma (penetrating versus blunt), SBP and GCS [18]. This score is easy to calculate in the prehospital settings and it is possible to define 3 groups of patients with different levels of mortality: low (2.8%, score 23–29), medium (15%, score 18–22) and high (48%, < 18 points). This score is correlated with the outcome, an ISS > 15, an intensive care unit stay > 2 days and the presence of massive haemorrhage [18]. However, it is poorly correlated with the probability of performing an emergency surgical procedure [60]. Among the scores currently available, it is probably one of the most interesting to use in the field for triage purposes. It is suggested that the score be calculated after the patient's initial prehospital assessment and the patient send to nearest trauma centre if the MGAP score is less than 23 [61].

4.4.4. Biomarkers

Over the past few years, point-of-care tools have been developed to measure haemoglobin, INR or the lactates and in a study; it has been found that the measurement of lactate in the prehospital settings could reduce over triage [62].

4.4.5. "Grade" classification

An alternative to scores is to propose triage rules that take into account vital signs initially observed at the first medical evaluation, type and localisation of injury, response to resuscitation, circumstances of injury and characteristics of the patients (medical history, age, treatment; Table 2) [10]. This approach was first described by Kienlen and de La Coussaye in 1999 [63] as a help to improve the triage of patients with severe trauma but also to initiate procedures for the preparation of the trauma resuscitation unit. This classification was closely correlated with the injury severity and in-hospital mortality [10]. Schematically, it includes grade A (uncontrolled vital distress, for example SBP < 90 mmHg despite resuscitation), grade B (stabilised vital distress) and grade C (no physiological distress but high kinetic and/or high-risk patient in relation to medical history or treatment; Table 2). This classification has been used for several years in our regional trauma system [10].

5. Evaluation and trauma registries

The establishment of a registry is one of the essential components of a mature trauma system.

The purposes of setting up a registry is to have an epidemiological description in each geographical area, to compare the trauma centres and to develop research projects, with the goal of improving medical practices and the quality of care [10,35,51,64,65]. The hospital that cares for trauma patients can therefore be evaluated on the basis of these registries. Initially set up at the level of each network, these registries are intended to unite, as it is the case with the German Trauma Registry (Germany) or the National Trauma Data Bank (USA), which gathers more than 1 million patients. In France, 3 registers exist, 2 of them in the Auvergne-Rhone-Alpes region and a more recent one in the Paris area (traumabase, www.traumabase.eu).

The setting up of morbidity-mortality meetings in each of the participating centres is also essential with the possible participation of experts from the network. Overall, it was observed that implementation of programs to improve performance was, with the triage of the patient to the good facility, the factor that allowed the greatest improvement in terms of survival [55].

6. Additional roles of regional trauma centres (level 1)

In addition to their clinical activities, the referral centres should develop a leadership through participation to research and teaching in the field of trauma [1,2,54], including elaboration of guidelines [66,67].

Organisation of trauma course is another way to improve trauma care and it can be organised within the university or scientific societies. These training courses can be also developed within the framework of a network and at this time concern all those involved in the management of poly-traumatised patients. For example, in Norway, training in Damage Control techniques was offered to teams from remote rural hospitals, resulting in improved quality of care [68].

7. Conclusion

The establishment of a trauma network is now seen as an essential element for improving the functional and vital prognosis of patients with severe trauma. This requires awareness from

policy makers and the medical community in order to obtain resources and adherence to the principles and rules of functioning of health care networks. The aim is ultimately to direct patients to hospital with the resources and experience necessary to manage their injuries.

Ethical Statement

None in relation with the nature of the article.

Contributors

JSD wrote the manuscript; PB and MR did critical reading and revised the manuscript.

Disclosure of interest

The authors declare that they have no competing interest.
JSD and PB did lectures for LFB (Les Ullis).
MR for MSD (Courbevoie).

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Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at https://doi.org/10.1016/j.accpm.2018.01.006.

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