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Original article

The 14 July 2016 terrorist attack in Nice: The experience of orthopaedic surgeons

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ABSTRACT

Background: On 14 July 2016, a terrorist drove a truck through the crowd on the Promenade des Anglais in Nice, France, killing 87 people and injuring 458. The objective of this study was to evaluate the management strategy used to handle the osteo-articular injuries caused by this attack.
Hypothesis: The management strategy used ensured that open fractures were treated within 6 hours.
Material and method: This single-centre retrospective study included all victims of the attack admitted to the Pasteur 2 Hospital in Nice, France, for osteo-articular injuries, and treated between 14 and 31 July 2016. The following data were collected for each patient: age, sex, type of injury, Injury Severity Score (ISS), whether the damage control orthopaedics (DCO) or early total care (ETC) approach was followed, time from injurytotreatment, operative time, and surgical revisions. The primary outcome measure was the injury to treatment time for each lesion.
Results: Of the 182 patients admitted to the emergency department, 32 required admission for osteo-articular injuries, including 18 with severe injuries (ISS > 15) and 11 with multiple fractures. Their injuries were of the type seen in traffic accidents. Of the 87 fractures, 45% involved the lower limbs and 25% were open fractures. Surgery was performed in 14 patients on the first night (14 to 15 July) and in 19 patients overall. The approach was DCO in 12 and ETC in 7 of these 19 patients. All lesions were managed within recommended time intervals, including the 21 open fractures and 2 closed femoral shaft fractures.
Discussion: Injury-to-surgery time complied with recommendations in all cases. In 25% of cases, ETC would have been feasible during the mass influx of patients without hospital capacity saturation.
Level of evidence: IV, retrospective observational study.

1. Introduction

On 14 July 2016, a terrorist attack in Nice caused mass casualties in a number similar to that seen during the 13 November 2015 attack in Paris [1]. A terrorist drove a 19-ton truck into a crowd of 30,000 people gathered on the Promenade des Anglais in Nice to watch the fireworks on Bastille day, killing 87 people and injuring 458 [2–4]. Trucks have repeatedly been used as readily available terrorist weapons [5]. The Pasteur 2 Hospital in Nice was called on to manage a massive influx of trauma patients just 1 year after it was opened in July 2015. France's White Plan for organising healthcare system responses to unusual events was implemented within 1 hour of the attack.

The objective of this study was to evaluate the management strategy used to handle the osteo-articular injuries caused by the attack. The working hypothesis was that the management strategy used ensured the treatment of open fractures within 6 hours.

2. Material and methods

A single-centre retrospective study was conducted including all the victims of the attack who sustained at least one osteo-articular injury and were admitted to and managed at the Pasteur 2 Hospital between 14 and 31 July 2016. Patients managed at the paediatric Lenval Hospital, private hospitals in Nice, or hospitals located further away were not included. Neither were those admitted to the Pasteur 2 Hospital but having no osteo-articular injuries.

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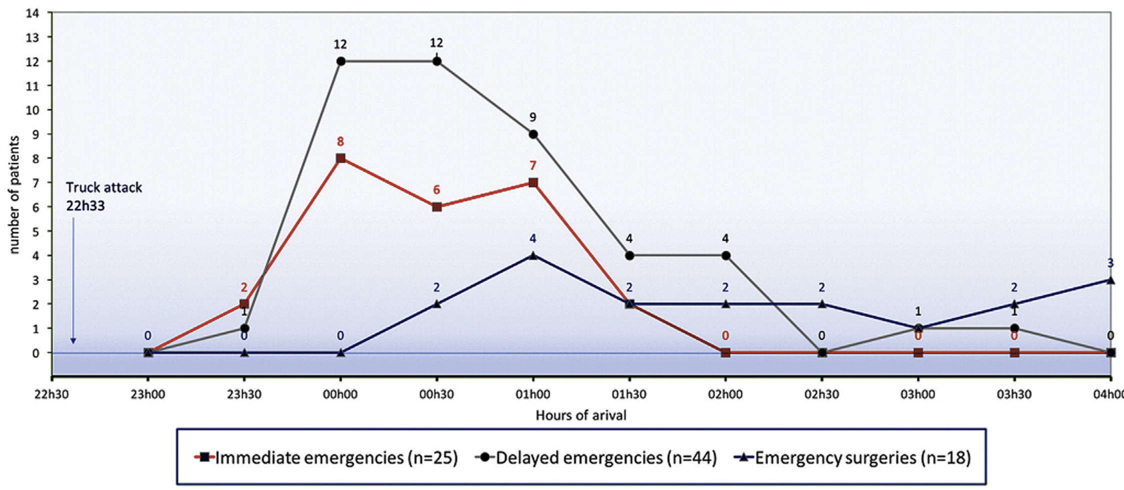

Fig. 1. Diagram of emergency admissions the evening of Bastille Day, 2016 (Based on the same influx of patients as Figure 1 of the article published in the *Lancet* [2]).

Finally, patients who were seen at the Pasteur 2 Hospital emergency department for osteo-articular injuries that did not require hospital admission were also excluded.

For each patient, the following data were collected: age, sex, fracture type, whether treatment was surgical or non-operative, type of surgical procedure, operative time, time from injury-to-surgery, need for revision surgery, the Injury Severity Score (ISS) [6], and whether the damage control orthopaedics (DCO) [7] or early total care (ETC) [8] approach was followed. The primary outcome measure used to assess the effectiveness of osteo-articular lesion management was the injury-to-treatment time. Time to treatment of open fractures was considered optimal when less than 6 hours elapsed between the injury and operating room entry [9]. For femoral shaft fractures, given the risk of fat embolus, the time target was 10 hours [10].

Pelvic fractures were classified according to Tile [11] and open fractures according to Gustilo [12]. Severity of the trauma was assessed based on the Injury Severity Score (ISS) [6], with severe trauma defined as ISS > 15. The time target for absolute emergencies (AEs) defined as life-threatening injuries, was less than 6 h from injury to operating room entrance. For relative emergencies (REs), the time target was 6–36 hours [13].

White Plan implementation was triggered by the hospital director at 11:30 p.m. The hospital had 38 cubicles available for patients with REs. To ensure the rapid management of AEs, 5 beds were available in the resuscitation bay and 8 additional beds for life-threatening emergencies were set up in the post-anaesthesia care unit. Patients already in the intensive care unit (ICU) were transferred to other institutions to free up 40 ICU beds for the pre- and/or postoperative care of severely injured patients. Throughout the night after the attack and the following days, the orthopaedic and trauma surgery team worked as pairs of one junior and one senior surgeon. Each pair was assigned to a specific role, i.e., triage, emergency room cubicle, resuscitation bay, or operating room. Triage was performed by a senior surgeon with triage experience (JFG) and an experienced anaesthesiologist/intensivist, and their decisions were recorded by a medical student. At the time of arrival of the first victims, 11 orthopaedic surgery residents and 13 orthopaedic surgeons were at the hospital. All surgeons of the orthopaedic and trauma surgery department went to the hospital after one of them received information from a witness of the attack, before the White Plan was triggered. This prompt response was allowed by the use of social media and massive, spontaneous solidarity. Of the 19 available operating rooms, 7 were dedicated to trauma surgery. A resident/senior surgeon pair and an operating room nurse in charge of surgical instruments were assigned to each operating room.

The decision to follow the DCO approach was made at operating room entrance of the first patient, at a time when 40 patients had already been admitted including 16 classified as AEs. Use of the ETC approach in the event of victim influx was not excluded, provided the system was not saturated. Of the 182 victims seen at the Pasteur 2 Hospital, 81 were registered during the first night, between 11:13 p.m. and 6:00 a.m. (when triage was stopped) (Figs. 1 and 2). Patient influx peaked between 1:30 a.m. and 2:30 a.m., with 47 patients in 1 hour. Mean time needed for triage was 2 min 27 s (± 1 min 45 s) per patient. Triage involved characterising patients as AEs or REs, assigning priorities for access to the operating room and computed tomography (CT) suite, and ensuring victim traceability. Between 11:13 p.m. and 5:30 a.m., 25 patients with AEs and 44 with REs were admitted. On the evening of the 14th of July, 39 patients required admission [2]. Among them, 2 died in the resuscitation bay, including 1 with haemorrhagic shock complicating a Tile C pelvic fracture and 1 with a severe head injury. In addition, 2 patients were deceased at arrival at the emergency room. Patients with isolated closed uncomplicated fractures of an upper limb were managed non-operatively and invited to seek care at one of the private hospitals in Nice or at a hospital near their place of residence.

3. Results

3.1. *Patients and lesions*

In all, 32 patients required admission for at least one osteo-articular injury (Fig. 2), 19 females and 13 males, with a mean age of 43 years (range: 14–84 years). Among them, 16 were admitted to a trauma ward and 16 to the ICU. Two-thirds were tourists and 50% from abroad. Eighteen had severe injuries (ISS > 15), 11 had more than one fracture (ISS < 15), and the mean ISS score was 21.7 (range: 1–59).

The 32 patients had 87 fractures, of which 45% involved the lower limbs (Table 1, Fig. 3) and 25% were open (Gustilo type I, $n = 9$; type II, $n = 7$; and type III, $n = 5$ with 2 type IIIA and 3 type IIIC). A single patient had an unstable pelvic fracture. Most of the injuries were those typically caused by traffic accidents, including 14 leg fractures, of which 10 (71%) were open (Gustilo type I, $n = 4$; type II, $n = 2$; type IIIB, $n = 2$; and type IIIC, $n = 2$). One-third of the fractures involved the spine but most caused no instability (fractures of

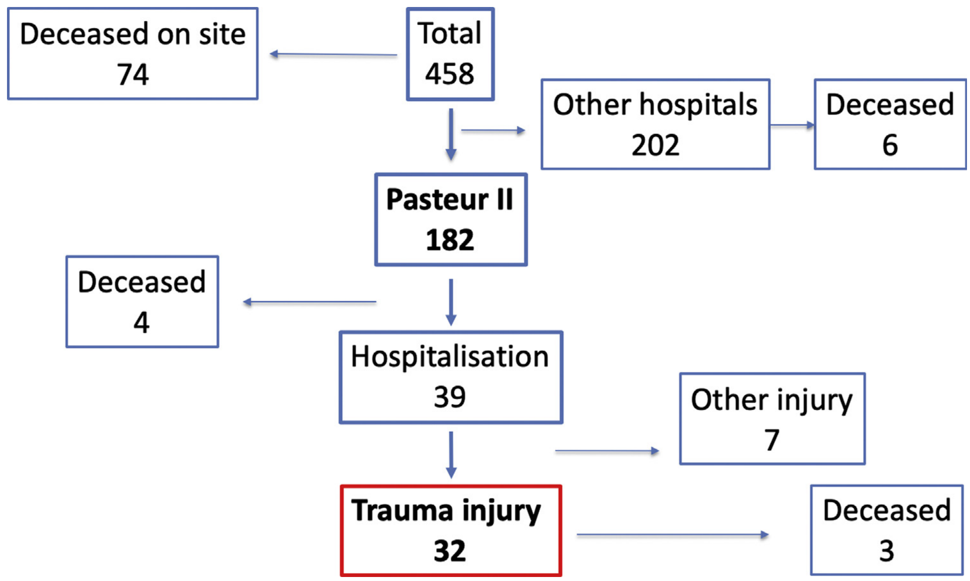

Fig. 2. Patient flow diagram.

Table 1
Number and site of the injuries.

Site	Number
Spine	24
Shoulder	8
Humerus	0
Forearm	2
Hand	4
Pelvis	8
Femur	2
Knee	9
Leg	14
Ankle	8
Foot	8
Total	87

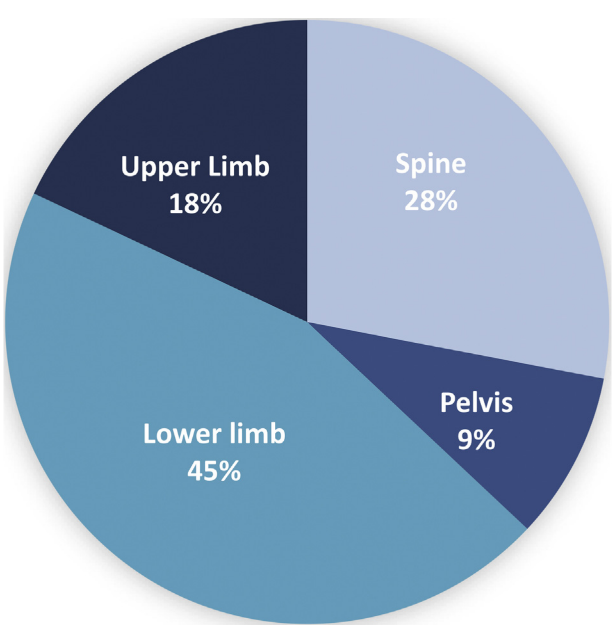

Fig. 3. Distribution of fracture sites.

the spinous or transverse processes) and only 1 (uniarticular C3–C4 dislocation) required surgery (Fig. 4).

3.2. Operating room activity

The operating room occupancy rate (Fig. 5) peaked between 1:00 and 3:30 a.m., when surgery was ongoing in 8 operating rooms and other procedures in 2 additional operating rooms. From 4:30 a.m. onwards, 2 of the 19 rooms were occupied.

During the first night, 14 patients required at least one surgical procedure performed by the trauma team, for 28 fractures. The procedures consisted of external fixation in 5 cases, irrigation/debridement followed by immobilisation in 18 cases, temporising trans-osseous traction in 1 patient, femoral intramedullary nailing in 1 patient, and trans-femoral amputation in 3 patients. During the first night, the DCO approach was followed in 12 patients. In all, 19 patients required at least one surgical procedure for 36 fractures, of which 80% involved the lower limbs. A review of the charts of the 12 patients who received DCO care showed that 7 would have received the same care regardless of the circumstances of their injury. In the other 5 patients, DCO was used due to the massive patient influx, but ETC would have been applied under usual working conditions. In the 7 patients who met usual individual-benefit criteria for DCO care, mean incision-to-closure time was 61 min (range: 10–105 min), mean time from injury to incision was 230 min (range: 100–310 min), and mean ISS was 26.5 (range: 9–50). In the 5 patients who received collective benefit DCO, mean time spent in the operating room was 45 min (range: 25–90 min), mean time from injury to operating room entrance was 178 min (range: 100–310), and mean ISS was 14.4 (range: 9–34).

The ETC approach was used in 7 patients after stabilisation in the emergency department and operating room. Among them, 2 had open fractures, with injury-to-surgery times of 4 h and 5 h, respectively. The other 5 patients had closed fractures and received deferred ETC once the massive patient influx had ended.

The 21 open fractures and 2 femoral shaft fractures were treated surgically within 6 hours. Mean injury-to-surgery time was 3 h 41 min (range: 100–360 min) for the open fractures and 4 h (range: 180–300 min) for the 2 femoral shaft fractures. Of the fractures, all but 2 were managed surgically within 48 h; the 2 exceptions

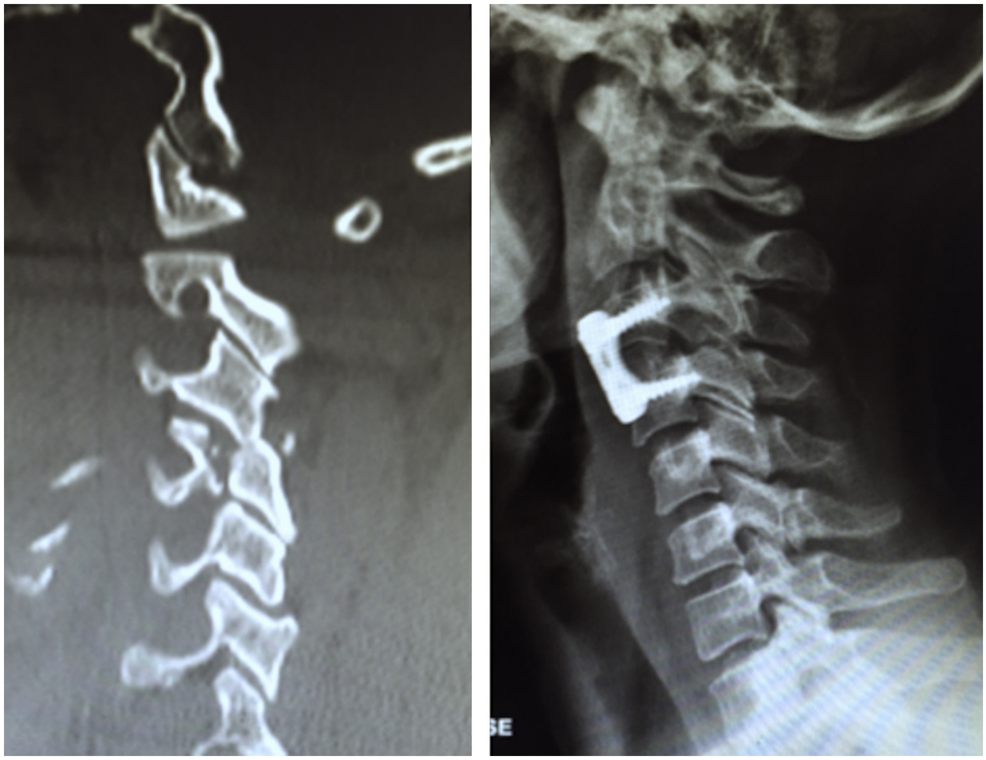

Fig. 4. Right uniarticular C3–C4 dislocation managed by reduction and C3–C4 fusion.

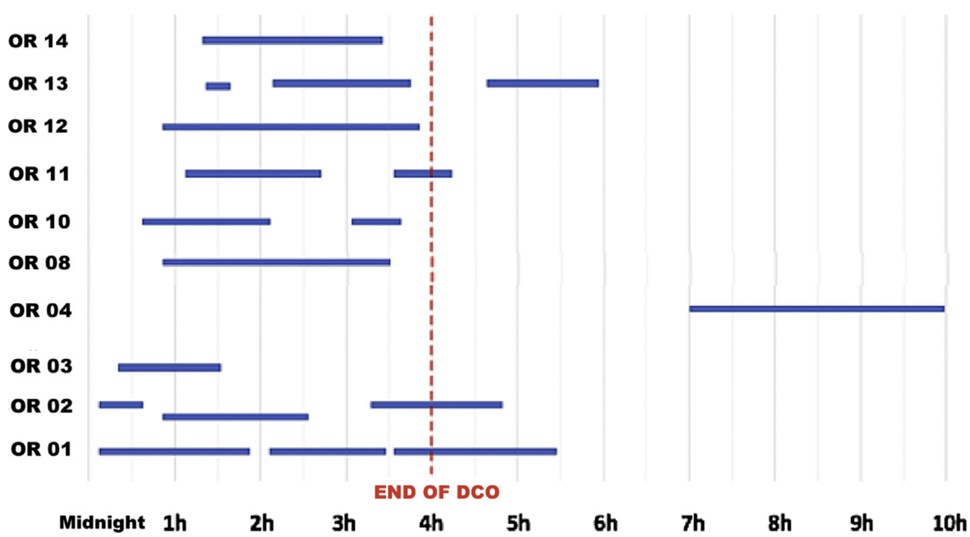

Fig. 5. Diagram showing occupancy of the orthopaedics and trauma operating rooms.

were a spinal fracture-dislocation that required halo traction before surgery and a secondarily displaced phalangeal fracture.

Of the 36 surgically treated fractures, 27 required a second surgical procedure. The reason for the second procedure was a dressing change in 30% of cases and external fixator removal with delayed nailing in 19% of cases. More than 2 surgical procedures were needed for 16 fractures, the reason being a dressing change in 82% of cases (Fig. 6) and a change in the internal fixation construct in 18% of cases (Fig. 7).

All 5 patients who received DCO care for collective indications required secondary surgery. In all, 8 surgical procedures in 7 patients were performed over the next few days, including leg external fixator removal followed by nailing in 2 cases, femoral external fixator removal followed by nailing in 1 case, external fixator installation in 2 cases, acromial pinning in 1 case, tibial plateau screw fixation in 1 case, and femoral condyle screw fixation in 1 case. The additional operative time needed to perform these procedures was 10 h 15 min.

4. Discussion

This study shows that all patients who required emergent surgery for osteo-articular lesions (open fracture, femoral shaft fracture, or pelvic fracture) had surgery performed within recommended time intervals. After the 2015 Paris attacks, France set up a White Plan to optimise healthcare organisation in the event of mass casualties [14]. A study in 7 Paris centres of patients who sustained osteo-articular injuries during the 2015 attacks helped to calibrate

Fig. 6. Appearance of a lower limb wound at repeated dressing changes.

the application of DCO for mass civilian casualties caused by combat weapons [15]. This study confirmed the usefulness of DCO for patients with open leg fractures and validated the use of ETC in patients with open femoral fractures caused by combat weapons.

The Nice and Paris attacks differ in several respects. In Nice, the victims had traffic accident injuries, as opposed to injuries inflicted by combat weapons. The high density of hospitals in Paris allowed the victims to be distributed over several institutions, whereas in Nice the Pasteur 2 hospital received 182 victims, including the adults with the most severe injuries. Our study therefore allowed an assessment of DCO used for collective benefit, a strategy previously described by Rigal et al. as a response option to mass casualties [16]. Under such circumstances, DCO can be used as a collective surgical strategy to ensure that the largest possible number of patients are managed within a narrow timeframe. In the event of a massive influx of trauma victims, DCO limits the operating time and the time to surgery in each patient to avoid overwhelming the management capabilities of the institution [17]. The disadvantage of DCO is that further surgery may be required in patients who otherwise would have been managed with a single procedure. We partially applied the DCO strategy after the Nice attack. Our results demonstrate that DCO used in a collective indication contributed to ensure that the hospital's capabilities were not overwhelmed. Nonetheless, the retrospective assessment of operating room availability showed that ETC, when possible, would have avoided secondary surgical procedures in 5 patients. Accurate real-time information about the situation as it unfolds, including exact patient counts, is consequently crucial to allow flexible adaptation of operating room organisation. Our decision to apply DCO was taken very rapidly, upon arrival of the first surge of victims (Fig. 1), at a time of considerable uncertainty about what was happening. Using all the operating rooms and maintaining a higher operating room occupancy rate would have allowed ETC in the more stable patients, thereby decreasing the need for further surgical procedures on the following day.

Several factors allowed us to avoided saturating our hospital's capacities throughout the management of the mass causality event. First, massive mobilisation of the entire hospital staff provided ample human resources. The Pasteur 2 Hospital, designated a level 1 trauma centre by the regional healthcare authorities, is a newly built hospital specifically designed to ensure that the resources needed to manage emergencies (emergency department, resuscitation bays, ICU, and operating rooms) are in close proximity to one another. This design ensured that all the needs of the most severely injured victims were rapidly met. The previous occurrence of the Paris attacks [1] had provided the opportunity to update the White Plan during the first half of 2016 and to identify and improve areas important to mass casualty management. Thus, before the European Football Championship (Euro 2016), which ended just a few days before the Nice attack, 25 external fixation platforms for simple constructs suited to DCO were sterilised. Finally, 14 July 2016 fell on a Thursday, creating a long weekend during which no elective procedures were scheduled, thus resulting in a large number of available hospital beds.

Previous evaluations of the Nice attack identified several problems, such as network saturation due to imaging study digitisation,

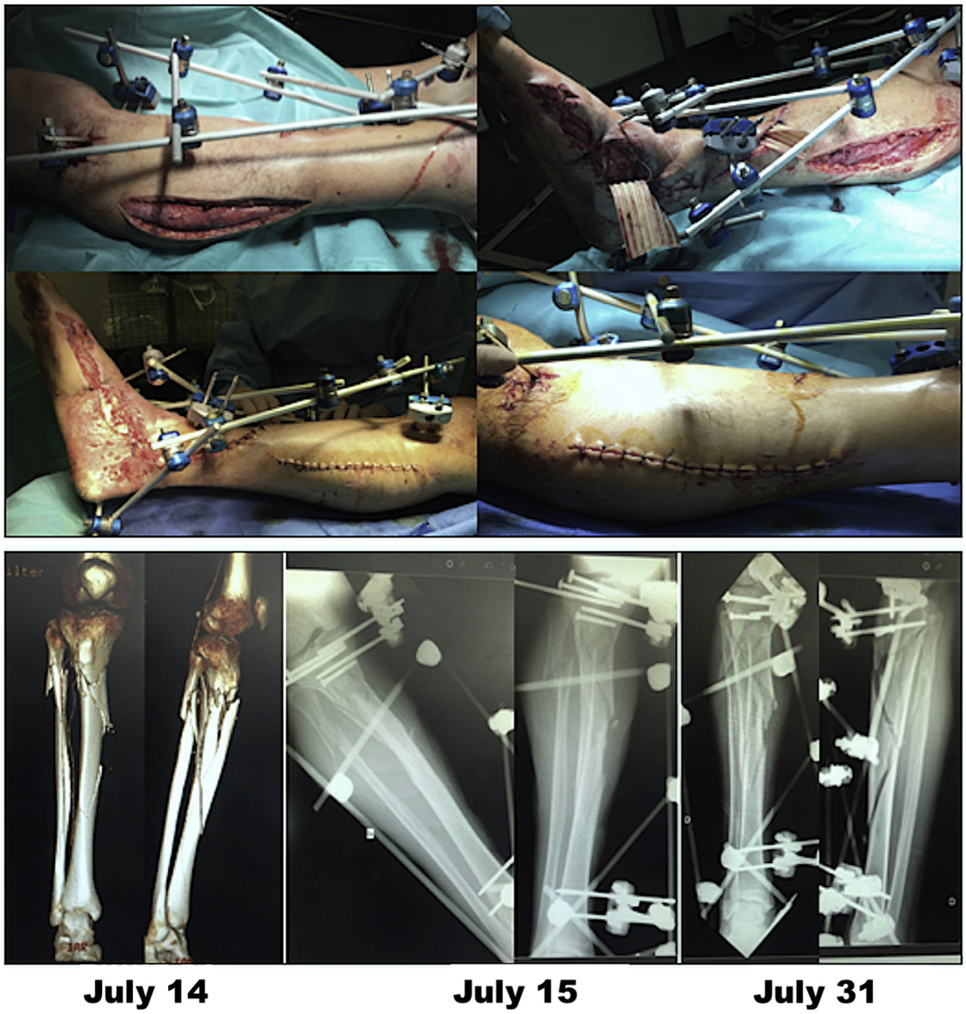

Fig. 7. Damage control orthopaedics approach used in a patient with complex tissue injuries.

telephone connection failures, and difficulties of individual patient identification [4,18]. None of these problems led to delays in patient management.

The limitations of this study include the retrospective and single-centre design, with inclusion of only those patients managed at the Pasteur 2 Hospital. Selection bias occurred due to pre-hospital triage, with the most severely injured victims being sent to the Pasteur 2 Hospital and the others to private hospitals in Nice or to hospitals in neighbouring cities. However, no patients were excluded from the study. All the imaging studies and hospital admission data were retrieved, despite the difficulties of patient identification. Furthermore, this study evaluated the implementation of a strategy for which the hospital staff had recently been prepared, and also identified areas for further improvement.

5. Conclusion

The massive and prompt mobilisation of the hospital staff, architectural design of the Pasteur 2 Hospital, training in White Plan implementation, and use of DCO ensured that the hospital was not overwhelmed despite the massive surge of trauma patients. All osteo-articular lesions in the Nice attack victims were managed within the recommended timeframes. However, one-quarter of the patients required further surgery after receiving DCO care at the time of peak patient influx.

The 2015 Paris [1] and 2016 Nice [2] attacks were the most deadly events experienced in France since World War II. They shocked both the general population and the medical community into awareness that appropriate responses needed to be developed. Each mass casualty event serves as a powerful catalyst for improvement. Reports of experience with previous mass casualities have prompted several actions that are ongoing or in preparation at the national and regional levels to optimise the management of mass casualties [3]. The main area for improvement is the training of a larger number of surgeons in the management of combat injuries and mass casualties. All surgeons should have basic knowledge in this field. A ‘Surgery in War and Catastrophes’ training module is now available to residents as a branch of curricula in other surgical fields [19]. It will allow military surgeons to share their knowledge with their civilian colleagues for use in circumstances where mass casualties occur outside combat zones.

Disclosure of interest

Jonathan Thomas, Lauryl Decroocq, Jean-Luc Raynier, Michel Carlesand, and Fernand de Peretti declare that they have no competing interest.

Jean-François Gonzalez receives consultancy fees from Corin and Léo Pharma.

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Contributions of each author

Jean-François Gonzalez: conceived the study and drafted and revised the manuscript.

Jonathan Thomas: data collection, drafted the manuscript.

Lauryl Decroocq, Jean-Luc Raynier: data collection.

Michel Carles: revised the manuscript.

Fernand de Peretti, Pascal Boileau: conceived the study.

Christophe Trojani: conceived the study and revised the manuscript.

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