

Modern teaching of military surgery: why and how to prepare the orthopaedic surgeons before deployment? The French experience

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Abstract

Purpose Improved survival of combat casualties in modern conflicts is especially due to early access to damage control resuscitation and surgery in forward surgical facilities. In the French Army, these small mobile units are staffed with one general surgeon and one orthopaedic surgeon who must be able to perform any kind of trauma or non trauma emergency surgery.

Methods This concept of forward surgery requires a solid foundation in general surgery which is no longer provided by the current surgical programs due to an early specialization of the residents. Obviously a specific training is needed in war trauma due to the special pathology and practice, but also in humanitarian care which is often provided in military field facilities.

Results To meet that demand the French Military Health Service Academy created an Advanced Course for Deployment Surgery (ACDS), also called *CACHIRMEX (Cours Avancé de CHIRurgie en Mission EXtérieure)*. Since 2007 this course is

mandatory for young military surgeons before their first deployment. Orthopaedic trainees are particularly interested in learning war damage control orthopaedic tactics, general surgery life-saving procedures and humanitarian orthopaedic surgery principles in austere environments.

Conclusion Additional pre-deployment training was recently developed to improve the preparation of mobile surgical teams, as well as a continuing medical education for any active-duty or reserve surgeon to be deployed.

Keywords Combat casualty · Humanitarian care · Military · Orthopaedic surgery · Surgical training

Introduction

Improved survival of injured combat casualties during recent asymmetrical conflicts was mainly due to advances in the battlefield medical support concerning immediate haemorrhage control, rapid in-theatre evacuation and early access to damage control surgery in Forward Surgical Teams (FSTs) [1, 2]. This modern practice is the legacy of the concept of the Larrey's flying *ambulances*, developed during the Algeria war (in the early 1950s) to create the French *parachutable* surgical units with the idea to bring surgeons as close as possible to the location of the action [3, 4]. Surgeons deployed in isolated small units must be able to perform any kind of trauma and non trauma emergency surgery for deployed allied personnel, civilian contractors and local nationals, including children and pregnant women. Humanitarian nonemergent care is also provided in these forward facilities during periods of low combat activity because it plays a substantial role in military operations [5, 6].

The fundamental deployed French surgical team consists of two surgeons: a general (visceral, thoracic, urologist or

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vascular) and an orthopaedic surgeon. Preparing these surgeons for war requires the development and maintenance of skill sets unique to the combat environment [7–9]. Since military surgeons are no longer general surgeons but monospecialists, they need to be trained as “general war traumatologists” [3, 4]. Concerning military orthopaedic surgeons, their peacetime practice does not differ from their civilian counterparts. They are working in military teaching hospitals embedded into the civilian medical support and practice prosthetic joint replacement, arthroscopic surgery and internal fixation for closed fractures daily. A few work in trauma centres receiving seriously injured patients similar to those treated in the war setting, but none of them practice neurosurgical, thoracic or abdominal life-saving procedures they may have to perform on the battlefield (Table 1).

As these general surgical skills were not gained in the standard French surgical training program, a pre-deployment training needed to be conducted for young active-duty surgeons and reserve surgeons. In order to meet that demand the French Military Health Service (FMHS) Academy created an Advanced Course for Deployment Surgery (ACDS) to fulfill the needs of surgeons prior to deployment regarding their ability to perform life-, sight- and limb-saving procedures, but also humanitarian care to local populations [10]. The main purpose is to keep polyvalence for the two team surgeons working together. This paper presents the specifics of surgery performed in modern military field facilities and training actions undertaken by the FMHS to prepare orthopaedic surgeons before deployment.

Specifics of war surgery

Several parameters make war surgery different from peacetime surgery (either civilian or military) and explain the need for an efficient specific training for military surgeons [3, 4].

The evacuation chain

Prior to arrival in forward surgical units, battlefield first aid and rapid aeromedical evacuation are crucial to ensure survival of hemorrhagic wounded. The main recent advances in this pre-hospitalization period (level 1) include the wide use of tactical

tourniquets, hemostatic dressings, intraosseous access for fluid resuscitation, and application of the Advanced Trauma Life Support (ATLS) principles that should be known by any field surgeon [11]. Then, the same patient may be successively operated on by different surgeons at different levels: FST (level 2), Combat Support Hospital (CSH, level 3) and military trauma centres after evacuation out of the combat zone (level 4) [12, 13]. This tactic imposes a standardized surgical practice, so that at each level, successive surgeons can easily guess what had been done before and what to expect [3].

Working with variable resources

If general surgeons may be deployed alone in very light and mobile life-saving surgical units designed to support Special Forces (Special Operation Surgical Team [SOST]) orthopaedic surgeons are only deployed in FSTs or CSHs [12, 14].

FSTs are light units of 12 personnel housed in tents or expedient shelters and deployed in isolated positions where immediate evacuation of casualties may be difficult (Fig. 1). The medical staff consists of a general surgeon, an orthopaedic surgeon and an anesthesiologist-intensivist. Diagnosis can be made by digital radiography and ultrasonography. Means of bone stabilization are limited to external fixation, K-wires and splints to perform Damage Control Orthopaedic (DCO) procedures.

CSHs are often located near to the airports in order to facilitate casualty strategic evacuation out of the combat zone. They are staffed by a multidisciplinary surgical team that may include a neurosurgeon, an ophthalmologist and an Ear, Nose and Throat (ENT) surgeon. These hospitals are equipped with a CT-scan, a blood bank, an intensive care unit, full laboratory capabilities and a pharmacy. Means of internal bone fixation and operative fluoroscopy are also available to provide definitive care to local nationals [12, 15, 16].

Treatment of specific pathologies

Whether conventional, non conventional or improvised, war weapons create a specific surgical pathology with predominance of extremity injuries [3, 17]. The difference between civilian and military trauma surgery is mainly due to the more extensive contaminated penetrating wounds, with superadded burns and physiological compromise due to blast injury [2].

Table 1 Difference between peacetime and wartime surgical practice

Peacetime practice	Wartime practice
Monospecialized	Multiple organs injuries
Few trauma surgery (except in trauma centres)	Trauma surgery only
One-step surgery	Damage control surgery
Mini-invasive surgery	Large approaches
Evidence Based Medicine (EBM)	Few EBM for trauma
Ideal conditions with legal concerns	Austere or non usual conditions



Fig. 1 French Forward Surgical Team (FST) deployed in the North Mali desert

Improvements in personal protective equipment and battlefield medical support have increased the survival rate in modern conflicts. As a result, new injury patterns appeared with devastating wounds combining multiple traumatic amputations, extensive extremity injuries, and pelvic, perineal or thoraco-abdominal lesions [16].

Facing mass casualty situations

A mass casualty incident with overloading of the medical care resources may happen at any moment in forward surgical facilities. In this situation, it is necessary to establish priorities of treatment in order to optimize the use of surgical resources to benefit the greatest number. This is the concept of *triage* established by Larrey during the Napoleon campaigns. Because of the ethical issues it raises, this categorization process is one of the most dramatic challenges a military surgeon may face. Triage in war has no direct civilian medical equivalent and requires preparation of any deployed medical unit [3, 18].

Use of specific surgical tactics

The management of multiply injured patients in an austere environment requires an assortment of damage control and definitive procedures specific to the context of war [19]. With extremity injuries, the strategy consists in saving the life, saving the limb and retaining the function. The first priority is to stop the bleeding by pelvic external fixation, surgical control of a vascular injury or life-saving amputation. The second priority is to restore the limb perfusion and to treat (or prevent) a compartment syndrome. The third priority is to prevent infection by wound debridement and external fixation according to the war DCO principles [20].

Maintaining general surgical skills

Without a neurosurgeon, the orthopaedic surgeon is in charge of cranial and spine injuries. He must be able to perform

decompressive craniotomies and manage penetrative or closed injuries of the spinal column and cord. He may also be involved in the treatment of facial and neck injuries, especially when an intermaxillar blocking is required. Furthermore, in case of unavailability of the general surgeon (for example, during a mass casualty incident) he may have to perform alone life-saving procedures such as tracheostomy, emergency thoracotomy or abdominal damage control procedures.

Humanitarian care in military field facilities

Besides the medical support to the military forces, forward surgical facilities also provide Medical Support to the local Population (MSP) [5, 6]. If the main objective remains assistance to populations, maintaining staff motivation through regular activity and improving relationships with the local population are nonetheless strategic objectives of MSP [6]. However, this practice has limitations: the use of the available resources must be restrained not to impair the medical support to the Forces; the low capacity of hospitalization imposes a rapid discharge or transfer of the patients to local hospitals; MSP may be interrupted at any moment for security reasons; and the patient follow-up is uncertain or impossible [6].

MSP must be distinguished from the care provided by neutral Non-Government Organizations like the Red Cross which is a neutral, impartial and independent institution ensuring the entire period of treatment for numbers of patients with much more limited resources [2]. Despite these differences, the challenges of training military surgeons to humanitarian care are very similar to those of the civilian surgeons working for these organizations: both must demonstrate adaptability and flexibility [2, 21]. Surgical ambition expectations should be low: complex surgical procedures with uncertain outcome should be avoided in favour of ideally unique short and efficient procedures performed within the strict confines of ethics and good medical practices.

Training the military orthopaedic residents

Rotations in teaching hospitals

Sub-specialty focus in training now takes place in the early stage of a surgeon's career [22]. In France, trainees have as little as one year of "common trunk" in general surgery and five years spent in their chosen specialty. For the military orthopaedic residents this "common trunk" classically includes two six month rotations: one in a general surgery department (abdominal, thoracic or vascular surgery) and one in a neurosurgical or plastic and reconstructive surgery unit. Another six-month rotation in a department of pediatric

orthopaedic and trauma surgery is also mandatory to learn the basics of pediatric trauma. The ability to manage injured children is effectively a vital requirement in modern theatres of operations where pediatric casualties represent a significant workload [22]. However, this standard French surgical training program remains deficient to develop all the general surgical skills required for military surgeons [3, 4, 10].

Rotation abroad

As a consequence of the unique and long experience of the FMHS in Francophone Africa, an eight-week trainee deployment in sub-Saharan French medical facilities (Chad, Djibouti) or in the Principal Military Hospital of Dakar (Senegal) was initiated. During these training missions residents develop their competencies in general surgery, including obstetrics, and gain experience in management of stab and gunshot wounds which are much more frequent compared to France [10]. Furthermore, they are prepared for challenges of providing humanitarian care in a combat zone which is now recognized as a priority of the military surgeon training [2, 5, 22].

Target training

During the early years of their residency, surgical trainees follow the same medico-military training program as all other students in the FMHS Academy (*Ecole du Val-de-Grâce, Paris*). In addition, trainees in deploying surgical specialties must validate the ATLS basic course and the ACDS, also called *CACHIRMEX (Cours Avancé de CHIRurgie en Mission EXtérieure)*. The purpose of this mandatory course created in 2007 is to teach the basics of general war trauma surgery and the principles of humanitarian care provided to local populations in military field facilities [10]. It is also open to specialist registrars and reservist surgeons as part of continuous professional development, and to civilian surgeons interested in humanitarian surgery.

The ACDS takes place during the two last years of the residency, and includes five modules of three days each, with 112 hours for the whole course. These modules enable students to develop their operative skills in military trauma surgery and enhance their understanding of the FMHS protocols and doctrine, especially concerning the MSP. In each module there are case reports and lessons learned by surgeons coming back from recent theatres of operations, lectures, hand on exercises and simulation skills taught on cadaver or live tissue (Table 2). The faculty consists of surgeons from all of the specialties, including ophthalmologists, ENT, pediatric, obstetric and gynecological surgeons. During the skills tutorials, students use the same equipment that they will have in the field facilities. Every module is designed to have a topic of interest for an orthopaedic surgeon and a visceral surgeon: they assist during the practices as they will when deployed (Fig. 2) [10]. At the end of each module, the trainees receive

a CD-ROM containing lecture supports, technical notes and phone numbers of referent departments to get specialist advice according to the telemedicine principles [23].

Module 1 is dedicated to generalities about the war wounded and to the organization of the Medical Corps on the theatres of operations (Table 2). This first part, which is also mandatory for military anesthesiologist residents, does not include surgical skill but demonstration of the technical equipment available in the forward surgical facilities.

Module 2 deals with management of extremity and soft-tissue injuries. Orthopaedic trainees have to learn the war DCO principles, which go beyond the frame of civilian practice DCO, and how to manage a burned patient in the acute period. War DCO is a staged management of single or multiple injuries imposed by the combat environment and based on systematic temporary external fixation (including for closed fractures). The aim is to allow transport to a higher level of care while minimizing complications [20, 24]. The aeromedical evacuation constraints (in terms of delay and flight duration) also influence the surgical practice on the field and, for example, consider prophylactic fasciotomies in situations at risk.

Modules 3 and 4 provide the basics of general surgery that are currently lacking in the civilian orthopaedic residency and may help to save life on the battlefield. Trainees must especially acquire the following operative skills:

- Craniotomy for evacuation of extra-dural or sub-dural haematoma
- Tracheostomy
- Median sternotomy, anterolateral thoracotomy and rapid emergency thoracotomy for major vessels and lung haemorrhage control
- Laparotomy, aortic clamping, splenectomy, liver packing, pelvic packing and intestinal perforation control
- Approach to sub-clavian and femoral arteries, temporary arterial shunting and definitive artery repair.

Module 5 is mainly dedicated to humanitarian care within the MSP setting. It is crucial to prepare orthopaedic surgeons to manage complex extremity traumatic sequelae and neglected injuries in austere environments, as well as the tropical extremity diseases they may encounter in sub-Saharan Africa [25, 26]. In fact, the practice of humanitarian orthopaedic surgery in forward surgical facilities is highly dependent on the available technical resources. In FSTs housed in tents, soft-tissue procedures should be preferred considering the variable hygiene of operating rooms. Bone stabilization must be carried out by plaster, skeletal traction or external fixator [19, 27]. In contrast, in CSHs or enhanced FSTs with conventional sterilization and operating room, internal bone fixation can be performed under strictly sterile conditions [25, 26]. This module also includes practical exercises concerning control of massive haemorrhage and vascular repair performed on live tissues (Table 2).

Table 2 French Advanced Course for Deployment Surgery (ACDS) content

Type of training	Module 1 Battlefield medical support	Module 2 Extremities & soft tissue	Module 3 Head & neck, spine, chest	Module 4 Abdomen & pelvis	Module 5 Humanitarian care & haemorrhage control
Lectures	Levels of care Rules of triage Damage control resuscitation & surgery principles Antibiotics use for war wounds Tactical & strategic medical evacuations Rules of command for an officer Legal concerns on the battlefield	Soft tissue injuries Upper & lower extremity injuries Hand injuries & infection Landmine foot & blast injuries Compartment syndrome Burns Vascular injuries Negative Pressure Wound Therapy (NPWT)	Brain injuries Face & neck injuries Ocular injuries Spine & spinal cord injuries Thoracic injuries	Abdominal injuries Thoracoabdominal injuries Renal trauma Pelvic, gluteal & perineal injuries Extended Focused Assessment with Sonography for Trauma (eFAST)	French doctrine for MSP Ethics in MSP Tropical diseases Obstetrics & gynaecology General & orthopaedic paediatric surgery Care after earthquake
Skills		Skill 1: upper & lower extremity external fixation Skill 2: fasciotomy, manual skin grafting, basic pedicled flap transfers Skill 3: Approach to femoral, popliteal & brachial arteries, thrombectomy, arterial shunting & repair	Skill 1: intermaxillar blocking, tracheostomy & thyrotomy Skill 2: burr holes and craniotomies Skill 3: sternotomy, anterolateral and Clamp Shell thoracotomy	Skill 1: eFAST Skill 2: organ approach & various manoeuvres, aortic clamping, intra-abdominal packing, laparostomy with NPWT Skill 3: pelvic packing, pelvic external fixation, ureteral repair by stent	Skills on live tissue: haemorrhage control, arterial shunting & repair, liver packing, suture of a heart wound
Additional	Demonstration of FST and SOST technical equipment	Demonstration of the PercyFx external fixator and devices for NPWT			

FST Forward Surgical Team, *SOST* Special Operation Surgical Team, *MSP* Medical Support to the local Population



Fig. 2 Management of a multiple injured patient with facial trauma in a Forward Surgical Team (FST)

Trainee assessment

Competence assessment is performed continuously during the military residency and based on Procedural-Based Assessments (PBAs) which are the recognized modality of conducting on-going formative assessments of surgical skills [19, 22]. Achievement of these index procedures is assessed using a scoring system similar to the one described by Shastri-Hurst et al. [22]. All trainees are also mandated to keep a validated log book of their surgical practice. At the end of each rotation, PBA forms and a log book are reviewed by the clinical supervisor. Furthermore, at the end of each ACDS module, basic science knowledge and the decision-making process of trainees are evaluated, as well as faculty performances using a feedback survey. The final certification as senior military surgeon is conditioned by validation of the five modules of the ACDS and, of course, by obtaining the civilian surgical specialty qualification.

Advanced and continuing training

Training surgical teams

If achievement of all of the general trauma surgery skills by a single surgeon is challenging, the collective ability of the deployed surgical team to effectively manage these emergencies is essential for operational effectiveness [22]. In France, a new ACDS module was created in 2012 to give FST members the opportunity to work together before deployment. This team module is comparable to the Military Operational Surgical Training (MOST) course developed by the UK Army [2, 19]. The focus is to allow surgical trauma team training for treatment of patients with typical war injury patterns and management of mass casualties incidents. This course includes simulation training in a fully mocked up FST housed in tents with

triage exercises, and surgical skills in live tissue labs concerning haemorrhage control and vascular repair (Fig. 3). However, the strong operational activity of French FSTs and their additional military training (including shooting, battlefield first aid and parachuting) do not currently permit training in civilian trauma centres as practised in the US Armed Forces [28–30]. Maintaining an elective surgery practice between deployments is sometimes challenging for young surgeons who can be deployed twice a year.

Continuing medical education

Because training does not stop with a certificate, surgeons need revalidation to ensure they remain competent [9, 22]. As continuing medical education is required for elective surgery in the civilian practice, continuation training is also needed for war surgery. In the FMHS revalidation is recommended every year for active-duty and reserve surgeons to be deployed. They must attend one ACDS (basic or team) module, or produce a debrief report or lecture after deployment.

Conclusion

Early specialization in general surgical training and advances in battlefield medical support have changed the approach to combat casualty management. Thus, the requirements for a modern military surgeon to be deployed are:

- An initial polyvalent training as “general war traumatologist” with a mandatory curriculum
- A regular activity for elective surgery, but also for emergency surgery with management of major trauma
- A continuous medical education in order to use and transmit the lessons learned from recent deployments.



Fig. 3 Training of a Forward Surgical Team (FST) team: resuscitation exercise using a simulation model

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