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Deployment of the Surgical Life-saving Module (SLM) in 2017: Lessons learned in setting up and training operational surgical units

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ABSTRACT

Introduction: The military operations carried out by the French armed forces, occasionally require the use of the Surgical Life-saving Module (SLM), to ensure the surgical support of its soldiers. Due to its extreme mobility and capacity of fast deployment, SLM is particularly useful in small-scale military operations, such as Special Forces missions. In 2017, the French SLM was for the first time used to ensure surgical support of allied forces, which were lacking forward surgical capabilities.
Materials and Methods: the SLM is a mobile, heliborne, airborne, surgical structure with parachuting capability onto land or sea, therefore essentially focused on life-saving procedures, also known as "damage control" surgery. Due to the need for mobility and rapid implementation, the SLM is limited to a maximum of 5 interventions or, in terms of injuries, to 1 or 2 seriously injured patients.
Results: Over a period of 2 months, 5 medical teams were successively deployed with the SLM. A total of 157 casualties were treated. The most common injuries were caused by shrapnel 561%), followed by firearms (36%), and blunt trauma (2.5%). Injuries included the limbs (56%), thorax (18%), abdomen (13%), head (11%), and neck (2%). The average ISS was 8.5 (1–25) with 26 patients presenting with an ISS greater than or equal to 15. The average NISS was 10.8 (1–75) with 34 casualties having an NISS equal to or greater than 15. The surgical procedures were broken down as follows: 126 dressings, 16 laparotomies, 7 thoracotomies, 12 isolated thoracic drains (without thoracotomy), 1 cervicotomy, 12 amputations, 7 limb splints, 2 limb fasciotomies, 2 external fixators and 1 femoral fracture traction.
Conclusions: The numerous SLM deployments in larger operations highlighted its ability to adapt both in terms of equipment and personnel. Continuous management of equipment logistics, robust personnel training, and appropriate organization of the evacuation procedures, were the key elements for optimizing combat casualty care. As a consequence, the SLM appears to be an operational surgical unit of choice during deployments.

Introduction

The military operations carried out by the French armed forces, occasionally require the use of the Surgical Life-saving Module (SLM), to ensure the surgical support of its soldiers. As noncompressible hemorrhage represents the most common cause of preventable battlefield death, SLM was thus designed to only ensure damage control surgeries as near as possible to combat zones in order to control hemorrhages and allow casualties a safe transfer to healthcare structures with larger medical capabilities. Due to its extreme mobility and capacity of fast deployment, SLM is particularly useful in small-scale military operations, such as Special Forces missions. In 2017, the French SLM was for the first

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time used to ensure surgical support of allied forces, which were lacking forward surgical capabilities,

Our first objective was to retrospectively analyze the SLM surgical activity carried out in these new settings in order to evaluate its capacity to adapt to larger military operations. Our second objective was to discuss the training methods of its personnel.

Materials and methods

The French Health Service SLM is a mobile, heliborne, airborne, surgical structure with parachuting capability onto land or sea. It was designed to be deployed very quickly, as close as possible to the frontline, and therefore to the casualties, whose outcome depends on early treatment, in particular the control of noncompressible hemorrhages. Due to the need for mobility and rapid implementation, the SLM is limited to a maximum of 5 interventions or, in terms of injuries, to 1 or 2 seriously injured patients. It is therefore essentially focused on life-saving procedures, also known as rescue surgery or "damage control" surgery.

In its standard format, the SLM is stored in 8 sealed containers with a total volume of 4 m^3 and a weight ranging between 650 kg and 1 ton (Fig. 1).

It is usually deployed under a 25 m^2 tent, set up in less than 10 min thanks to a compressor. It can also be deployed on a boat, airplane, or any other solid structure (Figs. 2 and 3).

Fig. 1. The Surgical Life-saving Module (SLM) stored in its 8 sealed containers.

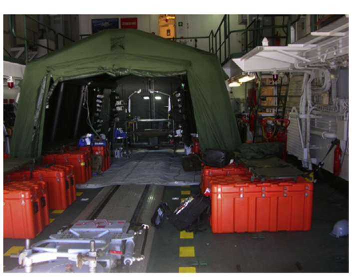

Fig. 2. The Surgical Life-saving Module (SLM) deployed on a boat.

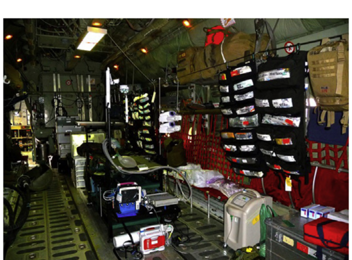

Fig. 3. The Surgical Life-saving Module (SLM) deployed on an airplane.

The personnel staffing this structure comprises of 5 team members: a "general" surgeon (gastrointestinal or cardiothoracic surgeon), a "head-neck" surgeon (oral and maxillofacial surgeon, otorhinolaryngologist or neurosurgeon), an anesthesiologist/intensivist, and 2 specialized nurses (1 operating room nurse and 1 nurse anesthetist).

The surgical and anesthetic equipment available in the SLM is primarily dedicated to performing rescue or "damage control" procedures such as laparotomy, thoracotomy, cervicotomy, craniectomy, vascular surgery (including hemorrhage control and vascular shunting or repair), and fracture management with external fixation; only one box of dedicated instruments is available per surgical specialty. The operating table consists of a "stretcher holder" system upon which the injured person, remaining on their stretcher, is placed, and equipped with armrest systems on either side. The operating light is provided by 2 surgical light systems fixed to the operating table in addition to a headlamp for each surgeon. The SLM does not have the capacity to hospitalize casualties so a rapid postoperative medevac is required.

The blood bank usually consists of 15 packed red blood cells units (PRBC), 10 lyophilized plasma units (PLYO), and 10 human fibrinogen units (CLOTTAFACT®), with the possibility, if necessary, of whole blood transfusion. Blood products are generally stored in a cooler with ice packs, equipped with blue tooth tracker to monitor temperature. This method allows a 7-day period storage. For a longer period, a fridge is generally required.

A "mini laboratory" is available allowing limited blood analysis such as hemoglobin count, electrolytes, HIV and hepatitis B/C assays, and blood group testing.

Imaging is based on a portable SonoSite TITAN ultrasound system. There is no X-ray machine.

Power requirement was provided by a 3 kVA generator, and when possible by local power source (national electricity grid).

During the various rotations, the SLM was setup in solid structures (often old houses abandoned during the conflicts) after mine clearance by combat engineers. Its deployment used to take approximately 45 min in order to become fully operational. It was divided into two adjacent chambers: an "emergency room" and an "operating room" (Figs. 4 and 5). All surgical materials were

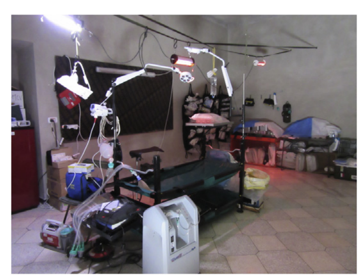

Fig. 4. The Surgical Life-saving Module (SLM) operating room during the 2017 military operations.

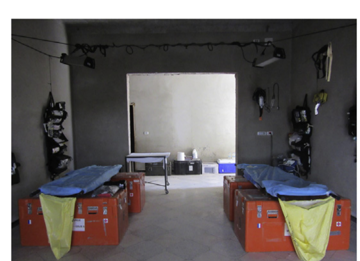

Fig. 5. The Surgical Life-saving Module (SLM) emergency room during the 2017 military operations.

sterilized by autoclaves in military hospitals in France following each deployment.

Force protection was ensured by host nation and coalition soldiers who also determined the SLM location, in coordination with host nation command. The SLM did not have its own communications. However, if needed, it was possible to use those of the coalition force protection. Living conditions were uneasy since no water or electricity were available in SLM locations due to war-related damage. The personnel were on rations and bottled water (not included in the one ton payload). SLM is generally deployed under a tent (excluding the accommodation tentage for the crew) but during these deployments abandoned houses were used (more protective than a tent). The staff usually slept in sleeping bags on floor carpets.

Local care chain organization

Before deployment, the local medical facilities which routinely dealt with war injuries, had been reviewed, and were deemed fit to treat seriously injured casualties especially after initial damage control surgery procedures. But these structures were at least four-hour drive far from the front line and had a poorly organized and equipped evacuation chain. As a consequence, and due to high early mortality rates, despite available combat casualty care, the host nation military command asked the coalition forces including French Military Health Service to provide forward surgical teams in order to play the role of intermediate medical structure between the front line and the distant local hospitals. During the study period, medical evacuations were only available by road.

Allied nurses, combat medics and sometimes general practitioners (GP), took care of the wounded on the frontline. After extraction from the combat zone, the casualties were gathered in a first triage zone and then transported by ambulance to either the SLM, which was the closest surgical outpost (approximately 5–10 km from the battleground), or to other local civilian hospital infrastructures located a four-hour drive from the combat zone. These ambulances were equipped with oxygen, and were usually staffed by a nurse, and rarely a GP, when the patient required forward resuscitation.

The casualties usually arrived without prior warning, with a peripheral intravenous line, dressings and occasionally a thoracostomy or a cricotomy. Tourniquets were commonly used for extremity hemostasis but as evacuation time to the local hospitals was quite long (minimum four-hour drive), casualties were transported to the SLM for tourniquet reevaluation and if necessary hemostasis.

The treatment received (e.g. resuscitation fluids, drugs) was documented on paper before evacuating the patient to a downstream structure. All patients were also evacuated with a written operative report (in English) detailing the injuries found and the procedures performed.

The casualties operated upon at the SLM were quickly evacuated, either awake or still intubated and sedated. The transfer method (mechanical ventilation, sedation, etc.) was decided by the SLM intensivist, depending on the patient's clinical status and evacuation conditions. Often the same ambulances that brought the patients to our SLM transferred them to the local downstream structures.

Statistics

Injury details (type, location, severity assessed by the Injury Severity Score (ISS) and New Injury Severity Score (NISS), management, and mortality in the SLM), were collected on an Excel® file.

The distributions of quantitative data were expressed as averages with range in brackets, and those of qualitative data as percentages.

Results

Over a period of approximately 2 months, 5 medical teams were successively deployed with the SLM. The average deployment duration was 10 days (7–15). A total of 157 casualties were treated with an average of 31 patients per team (7–58). They arrived in 41 successive waves with an average of 3.8 casualties per wave (1–13). All casualties were civilian males (100%), usually young. No information was available concerning their specific age, health status or comorbidities due to the local context. During these SLM deployments, there were no rules of eligibility since all patients were brought in by the host nation first aid teams which were the only medical units available near the combat zone. Patients evacuated to the SLM were for the majority fighters but some were civilians (approximately 5%). No children were managed at the SLM though pediatric anesthesia equipment was available.

The most common injuries were caused by shrapnel (n = 95, 61%), followed by firearms (n = 57, 36%), and blunt trauma (n = 4, 2.5%). Only one non-trauma-related admission was reported (n = 1, 0.6%). The casualties most often suffered polytrauma, with an average of 1.6 injuries per injured person. Injuries included the limbs (n = 140, 56%), thorax (n = 45, 18%), abdomen (n = 34, 13%), head (n = 27, 11%), and neck (n = 5, 2%). The average ISS was 8.5 (1–25) with 26 patients presenting with an ISS greater than or equal to 15. The average NISS was 10.8 (1–75) with 34 casualties having an NISS equal to or greater than 15. These 34 patients were indeed considered as "seriously" injured. In this group of casualties who needed immediate resuscitation and / or surgery, all had penetrating injuries; involving mainly torso (68%; n = 23), limbs (23%; n = 8), and head/neck (9%; n = 3). The majority had a polytrauma (73.5%, n = 25), and were hemodynamically unstable (91%; n = 31) upon admission at the SLM.

The surgical procedures were broken down as follows: 126 dressings, 16 laparotomies, 7 thoracic surgeries, 12 isolated thoracic drains (without thoracotomy), 1 cervicotomy, 12 amputations, 7 limb splints, 2 limb fasciotomies, 2 external fixators and 1 femoral fracture traction. Three patients had solely palliation as injuries were beyond any medical or surgical resources. There were 23 torso operations in 22 patients (1 patient with right thoracotomy and laparotomy).

During the cervicotomy, the patient underwent lateral oblique neck incision for shrapnel extraction and soft tissue debridement. This procedure did not include vascular, airway, esophageal or orthopedic surgery.

During the 16 laparotomies, the surgical teams performed liver packing (n = 1), liver suture repairs (n = 1), four splenectomies, 2 total nephrectomies, 5 colectomies without anastomosis, 1 omental hemostasis, 5 gastric suture repairs, 4 small bowel or colon suture repairs, 17 small bowel resections including 13 without anastomosis and 4 with anastomosis, 1 bladder suture repair on a cystostomy probe, 3 diaphragmatic suture repairs, 3 retroperitoneal packings, 2 pelvic packings, and 4 hemostasis procedures in the mesentery or mesogastrium. One laparotomy was solely exploratory. The damage control laparotomy indication depended on the surgeon. It was however, generally performed in critically injured patients with hemodynamic instability or in case of mass-casualty incident [1]. Small bowel anastomoses were performed in patients without hemodynamic instability and/or multiple injuries. In case of damage control procedure, the abdomen was left open using negative pressure wound therapy dressing kits when available, or "home-made" ones or just skin closure [2]. No specific policy concerning colostomy existed in host nation patients; it depended on the surgeon and the encountered injuries.

The seven thoracic surgeries included 3 anterolateral thoracotomies, 3 bilateral anterior thoracotomies (Clamshell incision), and

1 sternotomy. During these 7 thoracic surgeries, surgical teams performed 11 atypical pulmonary resections or “wedges”, 3 pericardiotomies (without fluid in the pericardium), 3 thoracic aorta clampings with internal cardiac massage in 2 cases, and pulmonary hilum clamping as well as intracardiac adrenaline injection in one case. The median sternotomy was performed for acute intrapericardial foreign body tamponade without associated cardiac injury.

Regarding transfusion requirements, 12 red blood cells bags, 7 French lyophilized plasma units, and 5 human fibrinogen concentrates were administered. Whole blood was not used during these deployments since no donors were available. Moreover, there was not enough staff to organize the whole blood transfusion chain.

A total of 5 patients died at the SLM (3% overall mortality rate). Among the five patients who died at the SLM, three were “beyond help”. These latter included two persons presenting with lacerated craniocerebral injuries and a $\leq$3 Glasgow score, as well as one case who sustained a diffuse shrapnel injury. This last patient presented with a more than 20 min-long cardiac arrest and without initial cardiopulmonary resuscitation. He had a slight cardiac activity on the electrocardiogram upon admission. These three “beyond help” patients only received supportive care. The remaining two died at the SLM from chest wound. Each had undergone a resuscitative thoracotomy with aorta clamping and internal cardiac massage. One of them had received intracardiac adrenaline injection. All the other casualties were evacuated and survived transfer to the different local downstream structures. No long-term follow-up could be carried out because of communication difficulties with these local care centers (lack of patient identity for example), short-term deployment and SLM mobility.

Discussion

Through this retrospective observational study, we report a high rate of surgical activity of the SLM over a short period with 157 patients treated and 190 surgical procedures performed in 50 days. However, this operational surgical unit, of a very small size compared to the surgical French role 2, is usually dedicated to the support of smaller military operations with fewer personnel involved, for example Special Forces operations (confidential data). Our study is in adequation with other reports of similar forward surgical units such as American Surgical Resuscitation Teams (SRT) in terms of team members and types of surgical procedures performed [3]. However, our study was conducted over a shorter period than Dubose et al. (5 months versus 12 years) [3]. Indeed, these recent SLM deployments have thus demonstrated the great adaptability of this small surgical structure in larger military operations, where the casualties had to be treated at saturation point. The ease and speed of its installation were major assets for these missions. Indeed, the SLM was deployed in various locations, difficult to access and close to combat, with limited transportation means. However, due to the large number of casualties, the SLM management capacity was regularly saturated, which required triage procedures and adaptation of personnel and equipment. The mismatch between the number of operated patients and the treatment capacity of the SLM could be managed thanks to the rapid implementation of adaptive measures. The high number of casualties was anticipated and large quantities of specific medical equipment were brought in advance as it was very difficult to re-supply the SLM during deployments. Short deployments were decided by the coalition command because French SLM was not the only forward surgical team on site and rotated with other coalition forward surgical teams (but this is confidential data). In addition, as already mentioned previously, it was very difficult to re-supply the SLM.

Transfusion was not a major constraint on SLM activity since 12 red blood cells bags, 7 French lyophilized plasma units, and 5 human fibrinogen concentrates were administered during these deployments as already mentioned in the manuscript. In addition, the length of deployments was in accordance with blood bank supply. As a consequence, we did not run out of stock.

Other measure consisted of establishing sterilization protocols as the SLU had only disposable surgical instruments, and therefore was not equipped with an autoclave. It was thus decided to use cold disinfection procedures by immersing instruments in ortho-phthalaldehyde (CIDEX®) solutions. This is common practice for endoscopic devices, and this technique is sometimes performed in combat zones with no other options for sterilization [4].

In case of SLM saturation especially when a surgical procedure was already in progress, triage was first conducted by the anesthesiologist/intensivist, leaving the nurse anesthetist in charge of anesthesia. The anesthesiologist/intensivist first evaluated the physiological parameters (Glasgow Coma Score, Systemic Blood Pressure, Respiratory Rate) then performed Focused Assessment with Sonography for Trauma (FAST) examination before being joined by one of the two surgeons (depending on the ongoing surgery) to assess the type of surgery needed and its estimated time.

From an epidemiological point of view, the injuries mainly involved the limbs, and were often soft tissues lesions, as reported in recent conflicts [5,6]. However in our study, we observed more chest wounds and fewer head injuries than other teams during the last Iraqi and Afghan wars [5]. We also found a slightly higher proportion of bullet wounds, and therefore proportionally slightly lower number of blast/shrapnel injuries than in other recent series, probably due to the fighting characteristics, and particularly their proximity to the urban environment [5,6].

The predominance of blast/shrapnel wounds in the limbs was responsible for the frequency of lacerating lesions. These latter were treated by surgical amputation, and very few with peripheral revascularization procedures [7]. Regarding the craniocerebral injuries encountered in our study, the majority were mild or moderate in severity, as previously reported [8]. It is however difficult in this context to assess the craniocerebral trauma severity, due to the absence of CT scan imaging, the variable Glasgow score assessed by the various personnel in the care chain, and lack of information on the neurological status during management [9]. Combat-related brain injury has a usually poor diagnosis. Thus, the decision to carry out a surgical rescue, or simple comfort care, is difficult, especially in mass-casualty influx situations requiring triage [10,11]. As a consequence, the presence of a "head and neck" surgeon appears essential within the SLM, in order to have the best possible expertise, and provide the most appropriate early treatment of these penetrating craniocerebral traumas, which are significantly longer surgical procedures. This extended operating time has to be taken into account during triage in the event of mass casualty [9].

We also would like to stress the importance of the SLM personnel skills, expertise, and communication, as the difficulty encountered during casualty influx was the simultaneous management of the emergency room and the operating theatre with - in theory - only 5 team members. This "multi-site" management required good coordination between the various SLM personnel. This involved having relatively autonomous specialized nursing staff such as the nurse anesthetist managing anesthesia/resuscitation in the operating theatre, while the intensivist had to treat severely hypovolemic casualties in the emergency room. The operating theatre nurse had to manage complex dressings by themselves while the surgeons were operating. Similarly, the specialized “head/neck” surgeon was required to carry out emergency procedures at the emergency room (such as thoracic drainage, resuscitation thoracotomy) while the "general" surgeon was performing life saving procedures in the operating room.

For these missions, a sixth nursing assistant coming from the armed forces was added to the 5 SLM personnel. This “paramedic” had previously been trained in the SLM procedures in France. Their presence made it possible to optimize the initial management of casualties in the emergency room during influx, and they could also act as an aid during surgical procedures when the presence of the second surgeon was necessary in the emergency room. The last aspect to be developed is the training of practitioners. Our results confirmed the relevance of deploying surgeons with broader skills than their initial training. To be eligible for deployment within the SLM, the surgeon must be a general surgeon with gastrointestinal/chest and vascular skills. These specificities can be acquired during the CACHIRMEX course and maintained through continuing practice in a trauma center. This aspect deserves all our attention in this period of French national transformation in the teaching of surgery. The reform of the third cycle of medical studies considerably modifies the training of surgery residents by imposing an early specialization, and as a consequence, abolishing the degree of general surgery. Although it is admitted that the “general surgery” degree has no longer been of interest in recent years, it remains necessary for future surgeons to have a wider set of surgical skills (“off-track skills”), particularly in the field of emergency surgery. In the reform of the surgical training program, these skills should be acquired during the first year of the fellowship, called the "core" phase of the third cycle. In the French Military Health Service, on the other hand, we consider that "off-track" skills are better acquired at the end of the fellowship. This is due to the fact that the fellows, at the end of their training, have sufficient surgical knowledge and skills in their field, to be able to quickly and permanently understand and acquire "off-track" skills.

To be eligible for deployment within the SLM, all surgeons must have received the specific "CACHIRMEX" training from the French Health Service, and must have already been deployed before within a role 2 forward surgical team. CACHIRMEX is the acronym for “Cours Avancé de CHIRurgie en Mission EXtérieure” (Advanced Course for Deployment Surgery in French). It deals specifically with military penetrating injuries, blunt trauma, non-traumatic emergencies and medical support to civilian populations in military healthcare facilities or austere environments. This 112 h course is spread over 2 years and broken down into five 3-day long modules of 20–24 h each. Each module is divided into 3 parts: lessons learned from recent deployments, lectures and workshops. Over a period of 2 years, it encompasses courses on the French Health Service organization during deployment, the French doctrine for Medical civic action program (MEDCAP), and finally combat-related trauma medicine. These modules include lectures and cadaveric workshops, and are based on the feedback from surgeons already deployed [12].

Conclusion

The Surgical Life-saving Module is a rapidly deployable and highly mobile forward surgical structure. The prognosis of combat casualties depends on early treatment. Therefore, it was initially designed to provide life-saving surgical support, as close as possible to the battleground, for small-scale military operations with fewer personnel. The numerous SLM deployments in larger operations highlighted its ability to adapt both in terms of equipment and personnel. Continuous management of equipment logistics, robust personnel training, and appropriate organization of the evacuation procedures, were the key elements for optimizing combat casualty care. As a consequence, the SLM appears to be an operational surgical unit of choice during deployments.

Conflict of interest

No conflict of interest.

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