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Original Research

Fixed Wing Tactical Aircraft for Air Medical Evacuation in Sahel

Pierre Guénot, MD [1,*], Vincent Beauchamps, MD [2], Samuel Madec, MD [3], Cyril Carfantan, MD [4], Mathieu Boutonnet, MD [5], Laura Bareau, MD [1], Hélène Romain, MD [6], Stéphane Travers, MD, Professor [7]

[1] French Military Medical Service, 186th Medical Service, Cazaux Air Base, France
[2] French Military Medical Service, 3rd Special Medical Service, Pau Special Forces Helicopter Squadron, France
[3] French Military Medical Service, 2nd Medical Center, Versailles, France
[4] French Military Medical Service, Operational Headquarters, Paris, France
[5] French Military Medical Service, Department of Anesthesiology and Intensive Care, Percy Military Teaching Hospital, Clamart, France
[6] French Military Medical Service, 105th Medical Service, Mérignac Air Base, France
[7] French Military Medical Service, 12th Medical Service, Villacoublay Air Base, France

A B S T R A C T

Objective: The medical support of military operations over a 5 million km^2 area in the Sahel-Saharan strip has justified the use of a medical fixed wing aircraft. Two CASA CN 235 aircraft currently perform medical evacuation (medevac) from the point of injury to forward surgical structures and then to the international airport before strategic medevac to France.

Methods: A retrospective observational study including all flights performed from January 2013 to December 2017 by the medical CASA located in Mali.

Results: Three thousand three flight hours were achieved. Four hundred twenty-four medevacs were performed for 898 patients. Seventy-five percent were evacuated from forward surgical structures. Their initial categorization included 10% Alpha, 23% Bravo, and 67% Charlie. Mechanical ventilation was performed for 5%; 34.5% had common medical or surgical pathologies, 34.2% were combat casualties mostly by explosion, and 18.7% were nonbattle injuries. No difficulties related to the aeronautical environment were reported by the teams.

Conclusion: Tactical medevac with fixed wing aircraft has become a crucial link in the French medical evacuation chain in remote areas. Military emergency medical teams were able to provide in-flight intensive care before and after damage control surgery. Discussions are underway to consider possible doctrinal and logistical evolutions.

Military engagement against terrorist groups in the Sahel-Saharan Strip (SSS) requires the implementation of a complex medical support plan because of the large size of the area and the constraints of a small logistic footprint on the ground. In this context of "tyranny of distances," 4,500 French soldiers, including 200 members of the French Military Medical Service, currently provide military support to 5 countries within an institutional framework called the "G5 of the Sahel."

French doctrine includes forward casualty care of the combat zone with advanced medical teams close to the combat units and tactical medical evacuation (medevac) from the field to surgical treatment facilities. Once stabilized with damage control surgery, patients benefit from early strategic medevac to France. This chain of survival allows the evacuation from point of injury to the homeland teaching military hospital in less than 30 hours.

The size of combat zones (more than 5 million km^2 or 2,123,561 square miles) has justified the deployment since 2013 of 2 CASA CN 235 medical transport aircraft. One is located in Mali and the other in Chad. These fixed wing aircraft allow medevac on larger distances in addition to helicopters that are already deployed. Their main missions are to transport casualties from the field to surgical treatment facilities or from surgical treatment facilities to international airports where patients can benefit from strategic medevac to France.[1,2]

The characteristics of the CASA CN 235 (range = 3,500 km, speed = 240 knots or 450 km/h or 280 mph, maximum altitude = 7,500 m or 25,000 ft, landing on summary runways with a front line

* Address for correspondence: Pierre Guénot, MD, 186th Medical Service, Cazaux Air Base, BP 70413, 33164 La Teste Cedex, France
E-mail address: pierre.guenot64@gmail.com (P. Guénot).

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of less than 1000 m, offered load capacity of 6,000 kg, pressurization, electricity, etc; Fig. 1) make it a particularly suitable vector for African medevac missions.[3] This is a satisfactory agreement between cost and efficiency.

The crew consists of 2 pilots, a flight mechanic, and a medical team consisting of a flight surgeon, a general care nurse, and a flight nurse. Operational alert is required 24 hours a day, 7 days a week. In case of emergency, the medical plane must take off in less than 1 hour. The CASA is mainly dedicated to medical evacuations. When operational activities decrease, it can sometimes reinforce other aircraft for material and passenger transport missions after agreement with operational command. The medical team and equipment always stay on board, allowing an immediate and flexible conversion to a medical version if needed.

The medical equipment and supplies enable care for 15 patients: 7 noncritical patients in a sitting position and 8 patients in a supine position, including a maximum of 2 critical patients (under mechanical ventilation). All medical supplies are packaged in air transportable boxes with wound and immobilization equipment (trays, deflatable mattresses, straps, etc). Prehospital intensive care kits include drugs, French lyophilized plasma, Oxylog 3000 (Dräeger, Lübeck Germany), Medumat respirators (Weinmann Emergency, Hamburg Germany), Epoc portable blood tests (Siemens Healthineers, Erlangen Germany), Hemocue (Baumann Medical, Wetzikon Switzerland), infusion pumps, vacuum cleaner, defibrillator, multiparametric monitoring monitor, and oxygen.[2] All kits are stored in the hold. They are ergonomic and standardized, making them easy to use (Fig. 2). The central part of the aircraft is left free to enhance medical team movement and facilitate patient boarding. The objective of this article is to describe the activity of this medical aircraft in order to assess its relevance and future developments.

Figure 1. Medevac Casa CN235-300.

Methods

This is a monocentric retrospective observational study of medevac CASA's activity deployed in Gao (Mali) from January 2013 to December 2017. The data were extracted from the medical evacuation reports and managed in an Excel (Microsoft, Redmond, WA) database. The data are expressed as values and means (± standard deviation).

Evacuated patients were classified according to the degree of emergency in accordance with the North Atlantic Treaty Organization STANAG 2087 standard.[4,5] This categorization sets out the following evacuation priorities:

1. Alpha: evacuation to a surgical facility requested in less than 90 minutes
2. Bravo: evacuation to a surgical facility requested in less than 4 hours
3. Charlie: evacuation to a surgical facility requested within 24 hours

Results

Characteristics of Air Medical Missions

In total, 3,003 flight hours were flown by the CASA detachment, which represents an average of 53.6 ± 1.9 flight hours per month. The distribution was 69% for day flights and 31% for night flights, with 48.8% of flight hours spent on medical evacuations. Overall, 424 medevac procedures were performed for 898 patients (Fig. 3) with an average of 2 patients per flight. In 2013, 344 patients (38%) were evacuated, which was at the beginning and peak of military engagement. The average number of evacuations and patients was 7 ± 2.7 per month and 15 ± 5.8 per month, respectively. The patients were mainly men (97%), French soldiers (88%), rarely foreign soldiers (6%), or civilians (6%). Their average age was 30.2 years ± 7.3 years. Of the

Figure 2. Medical kits and equipment in the aircraft.

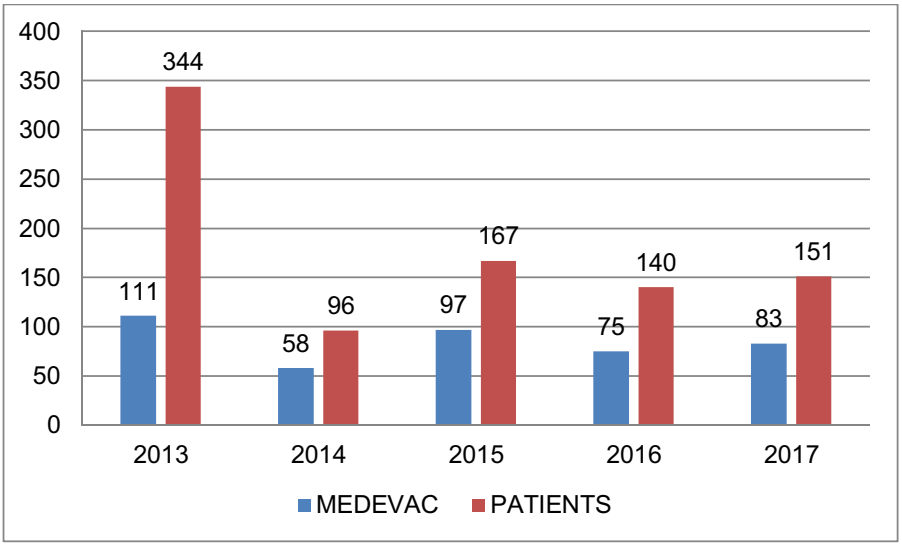

Figure 3. The number of medevac missions and evacuated patients between January 2013 and December 2017.

898 patients, 147 were excluded from the study because of the lack of available medical data. Thus, our work focused on 751 patients.

In total, 338 (45%) were transported in a litter or semiseated position, with 413 in a seated position (55%). Overall, 75% of patients were managed by CASA's medical team from the operational platforms of Gao (41%) and Tessalit (34%) where surgical structures are deployed and less frequently from Timbuktu (10%), Niamey (7%) and Ouagadougou (3%). The average flight time was 3.5 ± 0.8 hours.

Medical Characteristics of Evacuated Patients

Emergency categorization was: 75 Alpha (10%), 173 Bravo (23%), and 503 Charlie (67%). Five percent of patients were intubated and under mechanical ventilation. The proportion of medical and surgical conditions (34.5%) and war injuries (34.2%) was equivalent followed by conventional trauma (18.7%) and veterinary, psychiatric, and dental problems (Fig. 4).

Figure 5 shows the distribution of the different medical and surgical pathologies. The most common included nephritic lithiasis, lumbosciatalgia, appendicular syndromes, maceration dermatitis and skin infections, chest pain, and malaria. The "other" category includes discomfort, dehydration, and heat stroke.

For common traumas, fractures predominated (35%) followed by sprains (20%), with 49% of injuries involving the upper limb, 32% the lower limb, and 19% the spine and face. Injury mechanisms in combat casualties were caused by explosions (60%), mainly because of improvised explosive devices, and gunshots (26%). Road, aviation, and parachuting accidents were much less frequent (<5% each).

War injuries were primarily limb related (29%) before isolated acoustic trauma (21%) and isolated acute stress states (16%) (Fig. 6). The proportion of multiple trauma (8%) and thoracic, vertebral, and cranial trauma (5% each) was low.

Discussion

Continuum of Care: En Route Care

It is essential for combat casualties to receive uninterrupted and high-quality care from the point of injury until final treatment in France despite the challenging context of the combat environment. Their survival depends on the continuity and adequacy of care provided by the entire medical chain to which medevac CASA belongs.[1,6] The context of "tyranny of distances" in the Sahel-Saharan Strip theater of operations can reduce the survival rate of injured people.[7] This requires complex medevacs with the possible need for a vector

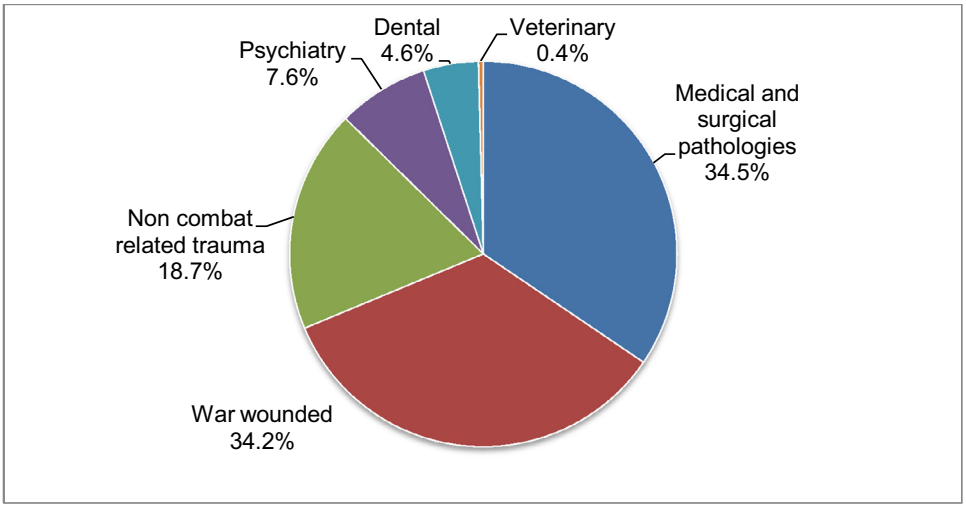

Figure 4. The main pathology of the 898 evacuated patients.

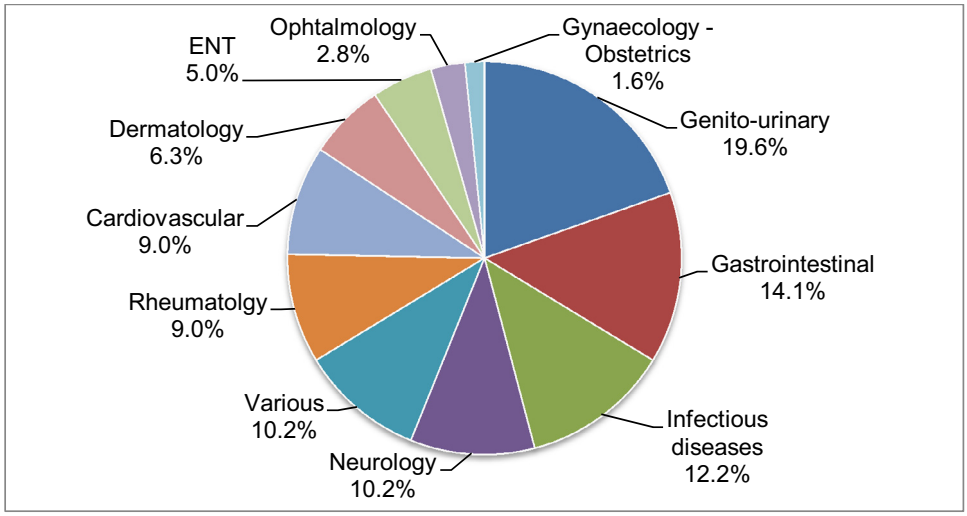

Figure 5. The typology of medical and surgical diseases (259 patients).

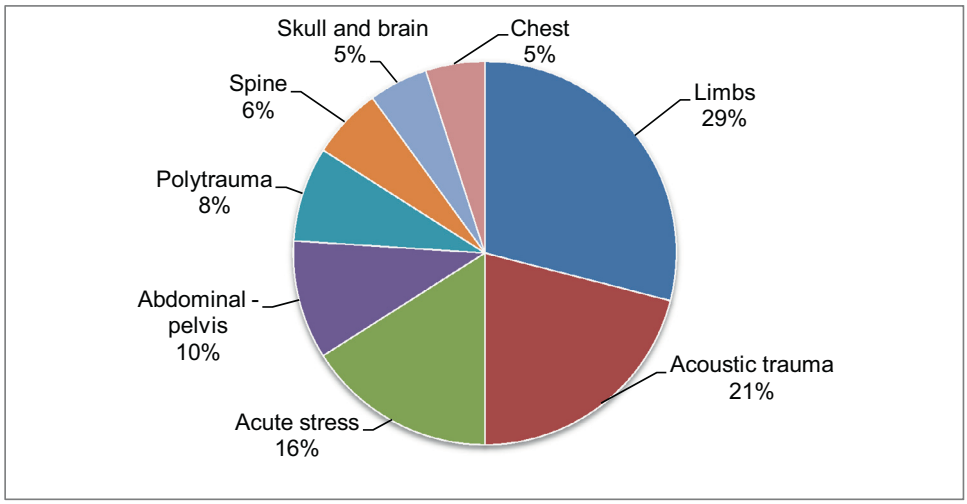

Figure 6. The typology of battle injuries (257 patients).

change. Thus, evacuation time before arrival at a surgical facility is long, and damage control resuscitation has to be provided as part of the prolonged field care management.[8,9] This is different from the Afghan theater, where the average evacuation time was less than 1 hour.[10] In a study conducted in 2016, Dubost et al[11] reported an average evacuation time of 390 minutes in Mali. The medevac CASA can cover approximately 1,400 km with an average flight time of 3.5 hours. The aim is to limit evacuation time and continue the therapies initiated at the front on the model of the US Air Force Critical Care Air Transport Team.[7]

Medevac CASA's priority mission is to perform tactical medical evacuation from the forward medical stations to the surgical treatment facilities (mainly Gao and Tessalit) and from ROLE 2 to Niamey, which is currently the departure platform for strategic evacuations in this area. The success of the mission depends on rigorous organization and the close coordination of the many operational medical teams by the Patient Evacuation Coordination Cell.[12,13]

In our study, the number of patients is lower than in the first months (January-September 2013) of Operation Serval.[2] The geographic distribution of medical stations, surgical treatment facilities, and medevac helicopters, as well as a lower intensity of combat actions, are probably the main reasons. Transport on litter is preferred for evacuation because of its suitability for the pathology presented and its relative comfort; the sitting position is reserved for nonpainful and noncritical patients. In our results, the distribution of patients according to their transport position and medical categorization (Alpha, Bravo, Charlie) is consistent with the literature.[2,9] The high proportion of combat casualties (34.2%) is explained by the intensity of fighting and the inclusion of isolated acute acoustic trauma and acute stress in this category. The mechanisms of injury and the anatomic distribution of injuries have changed during recent conflicts such as those in Iraq and Afghanistan. The characteristic of these modern conflicts is their unconventional and asymmetric nature. The majority of combat injuries identified in our study were mainly caused by explosions (60%) before gunshots (26%). The frequency of extremity wounds is easily explained by the lack of comprehensive ballistic protection and the effect of improvised explosive devices with a high-intensity explosion, widespread shrapnel wounds, and amputations.[14,15] Acute renal lithiasis caused by dehydration and limb trauma caused by excessive stress are the most common pathologies.

Flight Restrictions

Flight constraints may affect the clinical condition of patients, although no such complications were observed during the study period.[1,16] Noise and significant thermal amplitudes (+50°C on the

ground/+20°C in flight) are the primary factors, although they are better controlled than in other aircraft (such as the C160 Transall).

These constraints can be compared with those described in other aircraft as follows:

1. Helicopters with tactical low-level flights: vibration can have consequences on the hemodynamics of an unstable patient or on the displacement of fracture sites
2. Aircraft dedicated to strategic air medical evacuations (eg, Dassault Falcon 7X) with high altitude periods (FL 150): nevertheless, the CASA pressure control system is less effective than these planes, which can induce hypobaric hypoxia and gas expansion in closed cavities. Acceleration at takeoff can also affect hemodynamic instability, which is common in war wounds. The position of the patient's head forward or backward of the cargo is determined according to the patient's hemodynamic condition. For this reason, a central rear position is usually chosen for the most unstable patients.

In-flight Medical Care

Critical patients benefit from adequate resuscitation and damage control surgery before transport. However, some remain unstable and require close monitoring and extended in-flight resuscitation (Fig. 7).[6,7,8,12,14]

The medical team conducts their duty before (reassessment, packaging, and loading) and during the flight. They must perform a set of emergency diagnostic and therapeutic actions including multiparametric monitoring; venous and arterial perfusion; orotracheal intubation; nasogastric, urinary, and thoracic tubes; and vasopressors, analgesia, and sedation. A targeted evaluation with ultrasound for trauma and onboard blood tests (Hemocue and Epoc) are systematically performed on Alpha patients.[17]

The value of early transfusion in the management of hemorrhagic shock is well established and was performed on 25% of Alpha patients.[18-20] Sixteen percent of all Sahel theater transfusions were initiated during medevac. Thus, the medical team can take advantage of the long evacuation time to continue resuscitation, which represents a real medical and logistical challenge.[7,8,10,20] Among blood components, French lyophilized plasma is the most frequently used because it is available immediately, but red blood cells and whole blood were also used during flight. No complications related to early transfusions have been reported.[20,21]

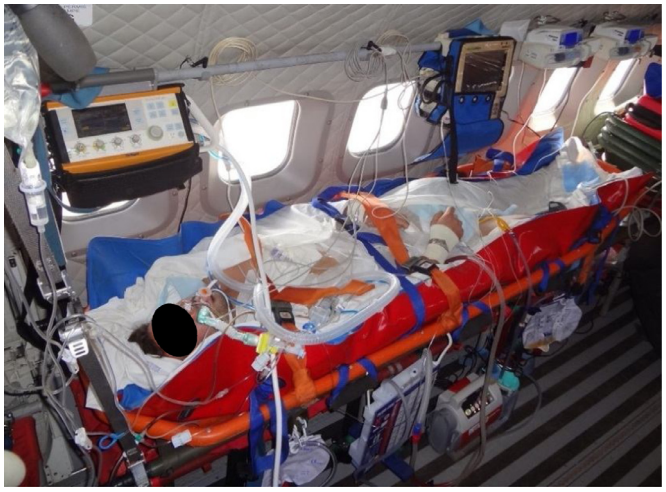

Figure 7. A casualty with penetrating chest trauma during air medical evacuation.

Medical teams undergo dedicated training performed by Val-de-Grâce Military Medical Academy before their deployment to familiarize themselves with these resuscitation skills.[22] This course aims to prepare nurses and physicians to 1) implement onboard equipment and the loading and unloading of patients in the aircraft and 2) used teamwork and human factors in a complex and austere environment. This training includes theoretical courses, feedback from recent operations, practical workshops on the ground, and in-flight medical simulations.

Limitations

Our work has several limitations. Being a retrospective study, the data came from the medevac reports. Results should be interpreted with caution because of the possibility of incomplete information. Also, 147 patients were excluded because of the lack of reliable and available medical data, mostly in the early stage of the operations, before the standardization of medevac reports. In addition, no information could be collected on patient outcomes.

Prospects for the Future

At the height of the military engagement, a maximum of 12 patients onboard and an average of 3.3 patients per flight were transported by the medevac CASA between January and May 2013.[2] Although the MEDEVAC CASA concept must preserve its adaptability, these figures could lead to a reflection on the permanent installation of a resuscitation module such as the one suitable for strategic aircraft. Maintaining mass casualty evacuation capacity could also be considered on a larger aircraft, such as the A400M, equipped with multipurpose medical batches.[23,24]

The CASA CN 235-300 has an onboard converter and is fitted with electrical outlets that can be used for high-power consumption medical devices, which is essential for long-term missions in which battery life is not sufficient. The initial medical kit was also gradually adapted as the missions progressed. Improvements should be proposed, such as miniaturization of certain devices and the installation of a multipurpose defibrillator monitor, allowing a reduction in the weight and volume of the package. The addition of a mobile emergency bag should also be decisive for medical interventions outside the aircraft, in particular for the support of special units. The installation of a battery cooler in the aircraft will soon be tested. This will improve the storage of emergency drugs and blood products, especially to allow the rotation of red blood cell or whole blood between the aircraft and the blood bank.

In addition, the air medical evacuation mission remains demanding and complex. Its specificities and constraints must be controlled by the crew. The transport of unstable patients in difficult areas and a long duration of flight requires both thorough knowledge of the aeronautical environment and experience in prehospital emergency medicine. The systematic use of well-trained emergency practitioners must be maintained. An ongoing study on the exact type and number of emergency procedures performed in flight by the medical team will undoubtedly improve the training of deployed medical personnel.

Finally, it seems essential to improve field data collection with a standardized database, as already done in the Joint Theater Trauma Registry by the United States or the United Kingdom.[25] This would help with quality of care assessment and clinical research projects. In addition, experience sharing between military and civilian teams is mandatory in order to improve both military care in operations and response to terrorist attacks in the national territory.[26]

Conclusion

After 5 years of operational deployment in Sahel, this concept of tactical transport aircraft medicalization seems to be effective. In addition to helicopters, fixed wing aircraft has become a crucial link in the French medical evacuation chain in order to mitigate the

consequences of distances and dispersion of soldiers over a difficult and expansive area. The key combination of aircraft, equipment, and medical team provides safety, ergonomics, and prolonged high-quality care. Based on limited results obtained thus far in this retrospective chart review, further data compilation is needed to prove the success of this mean. Discussions are underway to further improve doctrine, equipment, and medical team predeployment training.

Supplementary materials

Supplementary material associated with this article can be found in the online version at https://doi.org/10.1016/j.amj.2019.05.007.

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