FSG 100-03
CLINICAL POST-EJECTION PROTOCOL

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Dec 2015	Extensive revision, adding information on ejection escape systems, survivablity, ejection trauma assessment, and mental health considerations.	**Air Div Surg**	**Y**

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BACKGROUND

1. Every Flight Surgeon and Basic Aviation Medicine provider (BAvMed) should be prepared to respond to aircraft accidents and incidents in accordance with reference A and with guidance from reference B. Ejection is a category of aircraft occurrence with distinctive biodynamic and mental health stressors. This Flight Surgeon Guideline assists the aviation medicine provider responding to an ejection accident and caring for aircrew post-ejection.

2. RCAF ejection seat aircraft currently include the CF-188 Hornet and training aircraft such the CT-155 Hawk and CT-156 Harvard II, as well as the CT-114 Tutor flown by the Snowbirds. RCAF ejection accidents are infrequent. There have been eight RCAF ejection accidents since 2005 involving 11 ejections (see Table 1).

Table 1: RCAF Ejections 2005-2014.

Aircraft Type	Number Ejectees	Date	Circumstances
CT-156	2	Jan 2014	hard landing
CT-155	2	Jun 2011	engine failure
CF-188	1	Jul 2010	engine failure at low altitude
CF-188	1	Nov 2010	disorientation
CT-155	2	Apr 2008	engine failure
CT-156	1	Apr 2007	inadvertent ejection on the ground
CF-188	1	Aug 2005	loss of control in a spin
CT-114	1	Aug 2005	engine failure

GENERAL INFORMATION EJECTION

Ejection Escape System

3. The ejection seat is a sophisticated automated escape system that, once initiated by the pilot, moves through a sequence that typically takes about 2.5 seconds from initiation until the pilot is in descent under full parachute canopy. Although systems differ, there are common phases of an ejection each with potential for injury to the pilot or occupant:

   a. Escape path clearance (canopy jettison/ fragmentation);

   b. seat ejection (force depends on Gz peak acceleration and rate of change of acceleration);

   c. wind blast;

   d. free fall;

   e. parachute deployment;

   f. landing; and

   g. post-ejection environment and survival phase.

4. The occupant is restrained to an ejection seat by a restraint ensemble that typically includes lap belt, two shoulder straps, and a crotch strap. The ejection escape system is initiated by pulling a handle. The specifics of the ejection equipment and sequence are aircraft/seat dependent. Aircrew Life Support Equipment (ALSE) for occupants in ejection seat aircraft includes dual layer flight suit (additional layers are weather dependent), life preserver survival vest (LPSV), helmet, oxygen mask and G-suit (depending on aircraft type).

Survivability and Injury Statistics

5. Current ejection systems are very effective due to advances in design and engineering. Later generation rocket assist ejection systems expose the occupant to less acceleration than early ballistic ejection seats, and modern systems widen the safe ejection envelope often to include a “zero-zero” scenario in which the aircraft can be standing still on the tarmac (zero altitude and zero airspeed). Ejectees survive over 95% of within-envelope ejections (ref C). Ejections outside of the design envelope have a lower success rate, generally reported around 25% (ref C).

6. Delayed decision to eject and ejection outside the envelope are key survivability factors. An analysis by altitude indicates that over 91% of ejections above 500 ft were survivable, while only 51% of those below 500 ft AGL were survivable (ref D). This is due to multiple factors including nature of the emergency, aircraft operating parameters such

as speed and bank angle, and the lack of time to prepare. Low-level emergencies are time-critical and an early decision to eject can improve the outcome.

7. Differences in aircraft types, ejection seats, aircrew equipment assemblies, and restraint systems make it difficult to extrapolate from the literature to an injury distribution the RCAF might experience. Recent studies report spine injury to be the most common injury in ejection (29 % of ejectees ref C; 42 % of ejectees ref E). The next most common injury is lower limb injury on landing (18%), followed by head injury (14%) and upper limb (9%)(ref C).

ACCIDENT RESPONSE

8. Details of Flight Surgeon/BAvMed initial response to an accident is described elsewhere (refs A, B, F). The aviation medicine provider making the initial response to a flight safety occurrence will continue involvement until the Flight Surgeon appointed to complete the aeromedical investigation or FSI has arrived. Generally this will be the DFS Flight Surgeon.

9. The responding Flight Surgeon/BAv Med priority is clinical care of survivors; however, liaison with the coordinator of the emergency response team is vital to ensure the patients and medical team are safe during the emergency response.

10. Ensure that the coroner or medical examiner is contacted without delay if there are fatalities (this might be done by the On Scene Controller (OSCER)). For more information please consult refs A and B.

Site Hazards at Ejection Accidents

11. There are many potential hazards at an ejection crash site as discussed during the Operational Flight Surgeon Course. Refer to references A and B as needed. The aviation medicine provider may be called upon to advise on biohazard or other health risks to the entire emergency response team.

12. There are many potentially explosive hazards at a crash site, including munitions, flares, armaments, ejection seat charges, ballistically activated canopies, pressurized gas bottles, LOX converters, high pressure aviation tires and even the LPSV and seat pack may include flares and pressurized .canisters. Chemical hazards include aviation fuels and fluids.

13. Biohazard requires that standard precautions are taken. Burning/burnt carbon or composite fibre and other risks require that gloves, disposable coveralls, goggles and N-95 mask or half face respirator with appropriate filter are worn. A P100 organic vapour cartridge is often the default choice.

Ejection Acceleration Limits

14. Finite limits to human acceleration tolerance have been established (ref G) and injury risk level can be calculated for each of the three acceleration axes (these

calculations would generally fall to the DFS Flight Surgeon). NATO specifications limit is 18 Gz.

15. Data from automobile accidents and tests of bone strength suggest that women may be more susceptible than men to injury at higher impact or acceleration levels; however, studies have shown that occupant's age, anthropometry, and vertebral bone dimensions all combine to influence the susceptibility to injury during impact acceleration experiments. Gender alone is not considered a primary risk factor since some women may actually be less at risk than many men (ref G).

Flight Safety Investigation – Responding Flight Surgeon Considerations

16. Toxicology should be drawn for every aircrew that ejects IAW ref A. MSTU and relevant collection and shipping procedures are outlined at ref A.

17. Once the patient is stable clinically, then Flight Surgeon attention shifts to initial investigation and preservation of evidence. A detailed inventory of injury including minor abrasions, lacerations, marks from clothing or restraint systems, etc. is to be recorded. Consider the cause or mechanism involved for each injury. Analysis of ejection biodynamics and landing forces can be very important in determining causes of injury or death. Injury analysis can assist with learning the cause or sequence of events in the accident. The Flight Safety goal is to determine the cause and relevant circumstances in order to prevent similar events or improve ALSE and ejection systems.

18. ALSE including flight clothing, G suit, helmet and mask, restraint systems, etc. will be quarantined pending DFS Flight Surgeon action.

CLINCAL FOLLOW-UP POST-EJECTION

Ejection Trauma Evaluation

19. The patient's immediate clinical management is the first priority. Analysis of the biodynamics and cause of injuries sustained by the aircrew is also a critical part of the investigation. Injuries may arise from multiple phases in the ejection sequence (described in para 3). Injury may result from the:

a. Emergency that causes ejection, such as weapons, fire or collision;

b. Canopy jettison or fragmentation may cause burns from "MDC splatter" (see section in this document on MDC) and cuts/abrasions from fragmented canopy (particularly if the helmet visor is not down or is torn away), flash burns, or more severe head and shoulder injury if the ejection is through the canopy;

c. Firing of ejection seat may cause spinal compression fractures or femoral fracture from contact with seat pan;

d. Entering airflow exposes the pilot to wind blast and perhaps violent seat tumbling that may cause flail injuries to extremities or head injury, (ejection seats have a drogue parachute or deployable aerodynamic panels to minimise tumbling);

e. Parachute deployment/opening shock can cause spine injury or head injury due to helmet and parachute riser interaction;

f. Landing commonly causes lower limb injuries; and

g. post-landing environment may introduce a host of hazards due to climate, terrain, hostile force action, etc.

20. **Spine**. The upward acceleration (+Gz) of the ejection seat is a high force mechanism that can cause traumatic injury to the spine. The majority of the fractures reported in modern ejection systems are anterior wedge compression fractures caused by combined vertical compression and forward flexion of the spine, although other types of fracture including severe burst fractures may occur (ref C). Even if the pilot is tightly restrained in ideal sitting posture, the line of seat thrust does not coincide with the long axis of the spine. The majority of these fractures occur below the midthoracic region. Peak incidence of spine fractures in ejection is reported to be around the T12 and L1 level (ref C). This location is due to the lever arm created by the inflexible thoracic spine as it joins the lumbar spine. One or several vertebrae may be affected. The likelihood of spine fracture depends on a number of factors such as: the pilot's weight and age; design of the seat and restraint system; and, aircraft velocity and attitude at time of ejection; however, positioning of the occupant is also an important factor. Ligament and intervertebral disc injury is also reported (ref E).

21. Many ejectees with ejection spinal fracture are asymptomatic (42% reported in ref E). Plain X-ray AP and lateral should be taken of the entire spinal column even if the pilot is asymptomatic. Routine computed tomography (CT) scan is not recommended and should be conducted only if clinically indicated.

22. Spine magnetic resonance imaging (MRI) should not be routinely done post-ejection. MRI is performed only if clinically indicated. MRI is not the most appropriate diagnostic tool for identifying bony fractures. MRI is more suitable for identifying soft tissue injuries such as suspected spinal cord lesions or ligament injuries. Bear in mind that in most circumstances there is no baseline pre-ejection MRI available for comparison which makes it difficult to interpret between incidental pathology and ejection-related pathology secondary to an ejection injury. MRI will identify additional injuries; however, the vast majority are of minor clinical significance.

23. Bear in mind that spinal injuries may be poorly-defined on plain x-ray due to limitations of plain x-ray for identifying minor spinal fractures, spinal ligament damage, and other soft tissue injuries caused by ejection. In one review of 31 aircrew that underwent MRI post-ejection found that 18 of 31 had sustained spinal fracture(s). The initial plain X-rays did not reveal the fractures in eight (44%) of those 18 aircrew with fracture (ref C).

24. CT scan is the preferred initial imaging for C-Spine clearance when indicated by clinical decision-making tool such as Canadian C-Spine Rule (ref H). Routine MRI after a negative CT of the cervical/thoracic spine is not supported by the current literature (ref I).

25. Those aircrew with symptomatic spinal compression injuries usually remark on acute back pain following ejection which tends to be alleviated by mild or moderate analgesia.

26. **Head trauma.** Head injury may occur at any stage of the ejection, including on exposure to windblast or ground landing. Patient assessment including mental status and full neurological exam is required and may need to be repeated. CT only as indicated for intracranial injuries or to rule out epidural or subdural bleeding. Traumatic brain injury/concussion is a consideration.

27. **Lower limb.** Parachute decent rate combined with terrain on landing are important factors influencing lower limb injury and fracture. Potential injury includes fracture of femur, fibula and tibia as well as soft tissue injuries of the ankle and knee (ligament, tendon, and menisci tears).

28. **Other trauma.** As clinically indicated.

29. **Fatal Injury**. IAW ref A MRI of the remains should be done when practical. The alternate is full body X-Ray both with all clothing and equipment in place and with the clothing and equipment removed. This imaging provides important documentation on injuries. Radiographic exams provide the best evidence and characterization of fractures, dislocations and presence of foreign material. Consult ref A for more information.

Miniature Detonating Cord (MDC)

30. Miniature detonating cord (MDC) is used to fragment the canopy before ejection in some RCAF aircraft such as the CT-156 Harvard II and CT-155 Hawk (as well as the Alpha Jet operated by Top Aces). MDC is an explosive material that is lined on its inner surface by a layer of lead. On detonation, the lead directs the explosion away from the occupant and through the substrate of the canopy causing it to shatter.

31. The explosion creates enough heat to melt the lead, and the melted lead can contact the pilot. Lead “splatter” is a risk to unprotected skin and the eyes. The RAF experience of MDC splatter burns has shown no documented cases of long-term problems. Metallic fragments on the surface of the skin tend to fall out as the superficial wounds heal. There is a theoretical possibility that lead fragments could become lodged permanently in soft tissues and that lead could be absorbed into the blood. There is no record of elevated blood lead levels from MDC exposure in any CAF or allied force member. Nevertheless, DFHP has identified a remote risk of elevated lead levels in the blood, even a number of years after the ejection (ref J).

32. The risk of retained lead fragments should be assessed in every ejection involving MDC using x-ray to search for fragments in the skin. These x-rays may be deferred by a week to allow sloughing of surface material. Superficial lead fragments are not of concern.

If fragments are deeply embedded or there is evidence for systemic exposure, baseline blood lead level should be done within a few weeks of exposure. Follow-up x-ray(s) and blood lead level should then be done one year later. Consult with DFS Flight Surgeon or Air Division Surgeon office when considering measuring blood lead level.

Mental Health

33. An ejection is a dramatic event with potential for mental health injury. The scant literature discussing emotional or mental health consequences of ejection suggest up to 40% of ejectees experience prolonged mental health issues (ref K). Prevalence of acute stress disorder after a traumatic event such as car accidents or assault in civilian population is estimated at between 5 and 20 % depending on the nature and severity of trauma (ref L).

34. Each ejection event must be considered on a case-by-case basis. Some may experience the ejection as a success of training and equipment where others may experience intense fear during the ejection followed by feelings of failure or guilt afterward (ref M). Thorough mental health evaluation and close follow-up is required to optimise return of well-adjusted and highly functional aircrew to duty. Those experiencing a traumatic episode often display symptoms of marked distress in the initial days and weeks after the event, but the majority tend to adapt and symptoms abate. If this is not the case, specialist psychiatric consultation should be considered and the treatment approach may include various forms of exposure, CBT and/or medication therapy. Management may include grounding or return to limited flight duties as part of treatment.

35. Acute stress reaction may occur in the initial month after exposure to a traumatic event. Acute stress disorder includes symptoms of intrusion, negative mood, dissociation, avoidance, and arousal. It often presents with severe levels of re-experiencing and anxiety in response to reminders of the recent trauma. This may lead to generalized fear, vigilance for further threats, and active avoidance of situations that stimulate recollections of the trauma. Diagnosis should be made only when symptoms cause significant distress or impairment.

36. Management in the initial 72 hours generally consists of conservative measures focussed on basics such as nutrition, hydration, sleep, as well as communication with supportive individuals in the unit and at home. Acute stress reaction can be diagnosed three days after the traumatic event; however, delaying the diagnosis until a week after the event may better identify patients who will benefit from treatment and are at higher risk of developing posttraumatic stress disorder (PTSD) (ref L). The goal is to distinguish between those with a normal and self-limiting stress response and those with severe acute stress responses. Treatment of acute stress response can have the additional benefit of limiting subsequent PTSD, which is diagnosed only after four weeks of symptoms following exposure to trauma.

Grounding and Ungrounding Considerations

37. All aircrew or other occupants who eject will be grounded and undergo thorough medical and mental health evaluation. As discussed above, both physical and mental health injuries and subsequent management must be considered and patient progress monitored closely by a Flight Surgeon when using specialist care providers. Flight Surgeon consult with Air Division Surgeon/ASCS is expected before ungrounding. 85% of ejectees return to flying in six months or less (ref E), while others may require more time, and a small percentage will not be able to return to ejection-seat aircraft.

38. Post-concussion syndrome may result from injury to head and neck and may develop in the first days following mild TBI. Aircrew experiencing post-concussion syndrome should remain grounded until resolution which may take several weeks or months. Guidelines for return to play for athletes are appropriate for ejection seat aircrew due to the physical demands of flying jets and potential for cognitive deficit.

39. Aircrew who sustain stable anterior wedge compression fractures usually require no invasive treatment, but should not fly ejection-seat aircraft for three to four months (ref C). Aircrew with fracture of multiple vertebrae are more likely to be grounded for six months. In contrast, an unstable spinal fracture that requires internal fixation will likely leave the pilot with a stiff segment of the spine and make the pilot permanently unfit ejection seat aircraft.

RESOURCES

40. Contact the DFS Flight Surgeon as soon as practical for advice and to collaborate on accident investigation components. 1-800-WARN DFS is a 24/7 pager for the DFS duty person who will connect you with DFS Fight Surgeon.

41. An alternate source of advice is the Air Division Surgeon office using office numbers during working hours and Div Surg Call cell phone on weekend or after hours only (204) 801-8983. Please refer to the Air Div Surg website for more detail on how to make contact.

42. CF H Svcs Aviation psychiatrist may be consulted on diagnoses or treatment plan for post-ejection mental health concerns.