LS.208

Aviation Pathology Notes

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I. Office of the Armed Forces Medical Examiner

A. **Notification required for deaths of all active duty military** personnel, including aircraft accident victims.
   1. 24-hour telephone number
      a) Commercial **(301)319-0000**
      b) (800)944-7912
   2. Information required
      a) Number of fatalities with names and SSN if available
      b) Local Jurisdiction Coordination
      c) Location of Remains
      d) Location of Mishap
      e) Aircraft type and brief description of mishap
      f) Contact names and number(s)

B. Consultation by Armed Forces Medical Examiner System
   1. Aviation and Forensic Pathology Consultant to Mishap Investigation Board -- Consultant to NTSB.
   2. On-site investigation team if Exclusive Federal Jurisdiction or if local medico-legal authority (coroner or Medical Examiner) will release jurisdiction to the military, is willing to share jurisdiction, or will allow military pathologists to perform autopsies under his or her jurisdiction.
   3. Aviation Pathology Consultation
      a) Evaluate mishap site and wreckage
         1) AFME on-site team leader will usually request helicopter support for aerial photography
         2) Local Army National Guard or Reserve aviation units are usually very supportive when requested if USAF rotary wing assets are not available
         3) Simple, helicopter-based 35mm photography is very helpful for reconstructing the mishap, mishap analysis and review by the OAFME, and board briefings

Paper presented at the AGARD AMP Lecture Series on "Injury Prevention in Aircraft Crashes: Investigative Techniques and Applications", held in Farnborough, UK, 24-25 November 1997, and Madrid, Spain, 1-2 December 1997, and published in LS-208.

b) Post-mortem examination of fatalities
c) Assist investigators with injury pattern analysis and mishap sequence reconstruction.
d) Written preliminary anatomic diagnosis list for all fatalities is provided for the investigators before the AFME consultant team leaves the area.
e) Provide appropriate documentation to board.
    1) Autopsy report within 5 working days of return to office, usually sent to NTSB / pathologist by express mail or FAX
    2) Photographic proof sheets by express mail within 5 working days of return to office and additional photographic products as requested by investigators.
    3) Toxicology report(s) within 10 working days of receipt by the OAFME Division of Toxicology in Washington DC. Report(s) sent by FAX or Express Mail

II. The Aircraft Mishap Investigation

A. Purpose of Accident Investigation
1. Prevent Accidents
    a) Identify cause factors
    b) Improve procedures and/or equipment
2. Minimize Injuries
    a) Identify injury mechanisms
    b) Improve procedures and/or equipment

B. Investigation Operations
1. Aircraft mishap investigation is a multi-disciplinary venture, usually involving local, state, and federal agencies in the initial stages.
    a) Local law enforcement personnel and emergency medical response teams are generally the first to arrive on an accident site. As in any emergency, their first priority is to provide assistance to the survivors.
    b) After this is accomplished, the crash site is secured to prevent looting and preserve evidence at the scene. There is a tendency by some rescue personnel to remove bodies and wreckage before proper documentation and legal authorization. This should be discouraged as valuable information used in accident reconstruction and injury pattern analysis is lost. Removal of remains from the mishap site without proper legal authorization could make

investigators subject to criminal prosecution.

2. Documentation of the crash site
   a) The location of bodies and body parts in relationship to the wreckage is documented using a grid system or by measuring from fixed references points. Flags or stakes with sequential numbers are placed at the site of each body or body part.
   b) The remains are then photographed before placement in a body bag for transport to the morgue. Under no circumstances should personal effects (i.e. jewelry, wallets, etc.) be removed from the body at the site. Clothing should remain on the body.
   c) Personal effects that are not on the body are numbered separately and their location in relationship to the body is noted. This may help establish tentative identification of a victim.
3. Photography
   a) The entire accident site is photographed since film is a cheap and excellent means of permanent documentation. The wreckage is photographed at different angles and the fatalities are photographed before removal to the morgue. The cockpit of the aircraft is photographed to help correlate injury patterns found on the bodies of the pilots.
   b) Ideally, aerial photographs of the crash site are obtained. This enables the investigator to easily evaluate and conceptualize the entire wreckage dispersion pattern including ground gouges produced by pieces of the aircraft. Infrared aerial photography can sometimes be used to show fuel spillage patterns and to enhance ground gouges.
4. Preventive Medicine
   a) Site safety
   b) Bloodborne Pathogens

C. TAKE THE PATHOLOGIST TO THE MISHAP SITE !

III. Survivability Analysis

A. Crash Forces

1. Definition
   a. Crash - a sudden change in velocity (deceleration) resulting in damage to aircraft and contents.
   b. Acceleration - rate of change of velocity = change in velocity

divided by the time required for the velocity change.

c. Force - mass time acceleration (or deceleration)

2. Data for mathematical estimation is derived from crash site evaluation, wreckage analysis, instrument analysis, radio transmissions, radar plots, witness statements, mission plans, operational instructions, etc.

   a. estimate aircraft velocity
   b. estimate ground impact angle
   c. divide aircraft velocity into vertical and horizontal components
   d. estimate horizontal and vertical stopping distances
   e. estimate horizontal and vertical crush distances
   f. use standard physics formulas to estimate forces note: you must choose (or guess) an approximate decelerative pulse shape.

3. Example: An aircraft impacts a wall at 60 knots. The nose is crushed 5 ft and the wall is crushed 5 ft.

   Stopping distance s = 5 ft + 5 ft =10 ft
   Velocity change = 100 ft/sec (60 knots initial velocity)
   - 0 (final velocity)
   v = 100 ft/sec

   Equation: $G = v^2/64s$
   G = (100 ft/sec)(100 ft/sec)/(64 ft/sec-sec)(10 ft)
   G = 15G

4. **Additional methods of crash force estimation**

   a. Aircraft damage reflects decelerative forces applied to aircraft during the crash
   b. Injuries reflect decelerative forces experienced by occupants during the crash

5. **Human Tolerance to Decelerative Forces** - depends on both magnitude and duration force. Experimental human tolerance estimates for 0.1 sec decelerations are listed below.

+ Gz (Eyeballs Down)	25G
- Gz (Eyeballs Up)	15G
± Gx (Eyeballs In or Out)	45G
± Gy Eyeballs Side	20G

B. Occupiable Space
1. Aircraft crush and fragmentation
2. Temporary deformation of structures
3. Aircraft structure usually destroyed 30-50G
4. Restraint systems reduce required occupiable space
5. Blunt force injuries reflect competition for occupiable space with equal and opposite forces exchanged by the occupant and aircraft structures. These local force exchanges often greatly exceed the estimated crash forces for the center of mass of the aircraft-occupant system.

C. Post-crash environment
1. Fire
2. Water

D. Medical survivability analysis provides input to crashworthy design.

1. **Engineers use the "CREEP" concept** to assess and improve crash survivability through crashworthy design. The acronym 'CREEP" is used to organize the important aspects of crashworthy design. Note the similarities to the medical evaluation of survivability based on crash forces, occupiable space and post-crash environment. *(See Appendix for additional information on the CREEP concept and crashworthy design)*

C= container. Did the airframe maintain integrity and preserve and adequate volume of living space and prevent penetration by objects?

R= restraints. Were they worn correctly and did they function as designed? Did they prevent or contribute to injury?

E= environment. Were there any features of he mishap environment which affected the ability of the occupants to withstand crash forces or make a rapid egress?

E= energy absorption. Did the airframe and seat absorb enough of the crash-force energy to protect the occupants from exposure to intolerable crash forces?

P= post-crash factors. Did a post-crash fire, toxic fumes, poor communication, inadequate training, etc., affect survivability?

2. Major contributions of crashworthy design
    a) Crashworthy fuel system
    b) Energy absorbing seats
    c) Restraint systems

IV. Injury Analysis

A. External examination and documentation of injuries (photographs) are usually the most important parts of the post-mortem examination of aircraft mishap fatalities.
    1. These injuries are often not the fatal injuries
    2. They directly reflect interaction with environment
    3. They may suggest internal injuries which are fatal as well as define the injury mechanism.

B. Decelerative Injuries
    1. Note that human bodies are more resistant to disruption than aircraft. Thus the accident victims may be the best source for evidence with which to reconstruct the mishap sequence.
    2. Pure decelerative injuries provide a medical scale for estimation of crash forces. The most reliable points on this rough scale are high-lighted in the list below.
        a) Vertebral body compression -- 20 - 30 Gz
        b) Fracture dislocation C1-C2 -- 20 - 40 G
        c) Aorta intimal tear -- 50 G
        d) Aorta transection -- 80 - 100 G
        e) Pelvic fractures -- 100 - 200 G
        f) Vertebral body transection -- 200 - 300 G
        g) Body fragmentation -- > 350G

C. Impact injuries
    1. Blunt force injuries reflecting man-machine interaction in competition for occupiable space.
    2. Often dependent to some extent on restraint systems
    3. Examples
        a) Control panel head impact and skull fractures
        b) Compression injuries of fluid filled viscera and organs with a capsule
            1) liver
            2) kidney
            3) spleen
            4) bladder
            5) heart

c) Rib fractures and resulting lacerations

D. Ejection injuries
1. Flail
2. Environmental hazards
3. Aircraft impact and trace evidence transfer
4. Blunt force injuries from out-of-envelope ejections into trees or ground

E. Intrusive injuries
1. Wire strike
2. Rotor blades and other aircraft parts
3. Bird strikes (trace evidence)

F. Thermal Injuries
1. Flash burns and reconstruction
2. Artifacts
a) Pugilistic posture
b) Amputations and incineration
c) Skull incineration and epidural hemorrhage
3. Evidence of life in fire
a) Soot in airways
b) Carbon monoxide

V. Control Injuries

A. Evidence of intimate contact of hands and/or feet with aircraft controls at the time of impact

B. Radiographs of hands and feet are essential

C. Classical injuries
1. Hands
a) palmar lacerations and trace transfer to gloves
b) fracture-dislocation of base of thumb, often with evidence of forces transmitted through the wrist and forearm.
c) linear fractures of metacarpals
2. Feet
a) plantar lacerations and damage to flight boots (x-ray flight boots which may have bent metal plate)
b) fractures of metatarsals, calcaneus, or (especially) the talus

D. Dorsal injuries suggest flail while palmar and plantar injuries are more consistent with control injuries

E. The absence of control injuries means nothing

VI. Toxicology

A. Carbon monoxide
   1. excellent indicator of exposure to products of combustion while alive, in-flight or post-crash, differential usually based on other injuries and circumstances
   2. Stable postmortem -- not produced or eliminated

B. Cyanide
   1. useless because on instability, postmortem production, and absence of analytical standards
   2. worse than useless because commonly known by public and press to be a poison

C. Alcohol
   1. Postmortem production as part of decomposition process
   2. Depends on location and time of sampling
   3. Vitreous fluid is best sample, urine if vitreous is not available
   4. Blood is worst postmortem specimen since it is not protected from the bacteria which produce alcohol
   5. Postmortem alcohol production often sloppy with bacteria also producing chemicals such as acetaldehyde, acetone, n-propanol, and/or n-butanol

D. Drug screens
   1. Self medication
   2. Illicit drugs

VII. Identification

A. Presumptive
   1. Visual
   2. Personal effects
   3. Physical features
   4. Flight manifest

B. Positive
   1. Dental comparison
   2. Fingerprint and/or footprint comparison
   3. DNA comparison
   4. X-ray comparison

C. Identification is based on comparison of premortem records with postmortem observations. Without available premortem records, positive identification may be impossible regardless of how much postmortem data is available.

APPENDIX
Crashworthy Engineering Design
CREEP (Acronym)

Crashworthiness refers to the ability of basic aircraft structure to provide protection to the occupants during survivable impact conditions. Engineers evaluate aircraft crashworthiness by considering: Container, Restraint, Environment, Energy absorption, and Post crash hazards.

CONTAINER

Light airplanes and small transports (2-12 passengers) - During typical crashes the longitudinal structure collapses causing the floor to break up and seats to tear loose. Landing gear and engine may penetrate the cabin.

Medium Transport -- The fuselage fractures with complete separation of fuselage of under seats. There are often inadequate exists to permit escape and fuel is often under the passengers

Large Transports -- Fuel, located in wings and under the passengers is poorly contained if approach speed is above 150 knots. The fuselage often fractures in front of and behind the wings and the seats are torn loose from the floor. Exits may be blocked by fuselage deformation or fire, especially the exits over the wings which contain fuel.

Helicopters -- Transmission, mast, and rotor blades often penetrate cabin. Deformable structure is often limited and fuel tanks are adjacent to areas occupied by passengers. Occupants are particularly susceptible to crushing in roll-overs and inverted crashes.

High Wing Transports -- Structure is weaker because there are no longitudinal keel beams, only cross beams. The wings may crush occupants as they collapse and there is less crushable aircraft structure under the passengers.

RESTRAINT

The purpose of the restraint system is to delethalize the environment. Proper restraint systems minimize occupiable space requirements and prevent the occupants from becoming missiles which hitting aircraft structures. The occupants should decelerate with the aircraft.

Restraint System Characteristics -- Restraint systems should not be elastic and should be as wide and thick as possible to distribute forces over the maximum area. Lap belts should cross the broadest part of the pelvis at a 45 degree angle. There should a be a simple, one-point release which is easy to operate without special training, but will not open accidently during a crash sequence or by the passenger's inadvertent actions. The restraint system should be attached (tie-down) to the most stable part of the aircraft.

Types of Restraint Systems

Lap Belt only - provides minimal restraint and subject may jack knife, resulting in injury to abdominal organs

Lap Belt and Shoulder Harness - provides good restraint for everything but lateral forces and submarining.

Four Point Harness - provides excellent restraint but occupant may slip down (submarine) through the bottom of the restraint system. This allows the lap belt to compress and injure abdominal organs.

Five point harness - includes a crotch strap which prevents submarining. This is the best restraint system but it is expensive and uncomfortable to wear.

ENVIRONMENT

Good aircraft design provides as much crushable structure as possible between occupants and the outer skin and enough stiffness so occupants aren't crushed. There should be sufficient safe exits and the structure should minimize roll-over and plowing during a crash. The interior should minimize loose objects during a crash. In the cockpit, collapsible, breakable control sticks, cyclics, collectives and control yokes to prevent injury to head or chest.

Seat design should recognize the vulnerability of the head and chest to injury as well as the effect of lower extremity injury in preventing escape (ankles broken by seats or feet trapped under rudder pedals).
Rear-Facing seats can provide the most crash protection for passengers if they are designed properly because they are better supported by the floor and will tolerate higher G loads but properly designed seats are much heavier than forward facing seats. Passengers are less comfortable and are more susceptible to flying debris during the crash.
Forward Facing Seats are the best compromise for economy, safety and passenger acceptance.

Side Facing Seats are very poor in a crash because proper restraint is extremely difficult.

ENERGY ABSORPTION

Crushable structure under the floor between the occupants and the bottom of the aircraft can attenuate vertical G's. The nose of aircraft (if crushable) can attenuate horizontal G's, but forces can actually be increased if the nose plows into the ground. For best crashworthy design, the nose should be sled-shaped and crushable. Seats should be designed to attenuate vertical G forces. Stroking tubes are the best seat energy absorbing devices but honeycomb and crushable foam are other acceptable materials. Foam rubber is not acceptable for crashworthy design because it is an elastic material which can store energy and then deliver it to the seat occupant all at once, producing dynamic overshoot which may double the crash forces experienced by the occupant.

POST CRASH HAZARDS

Fire is the most important post crash hazard. Post crash fire occurs in approximately 20% of crashes but 65% of all aircraft accident fatalities are due to post crash fire. If there is no post crash fire there is a 90-95% chance of survival but there is only a 60-65% chance of survival if there is a fire.

Post crash fires produce abundant heat which can severely injure the occupants, but most victims of post crash fire die from inhalation of toxic products of combustion such as carbon monoxide and other chemicals from upholstery and interior surface covering material. In addition, the fire uses all of the available oxygen in the closed cabin, producing a severely hypoxic environment very rapidly. Most victims of post crash fires are unconscious or dead by the time their bodies burn from the heat.

There are multiple ignition sources in an aircraft crash. Fuel, oil and hydraulic fluids burn readily once there is an ignition source. Fuels must be a vapor (or mist) to burn but once vaporized, all fuels are equally flammable. Advanced fuels such as JP-8 and anti-misting fuels are more resistant to ignition after a crash. Oil and hydraulic fluid have broad flammability ranges and cling to surfaces.