Post Crash Fire and Blunt Force Fatal Injuries in U.S. Registered, Type Certificated Rotorcraft

A Collaborative Project between:

Rotorcraft Directorate Standards Staff, Safety Management Group

and

CAMI Autopsy Program Team, Medical Case Research Physician, and CAMI Biostatistician

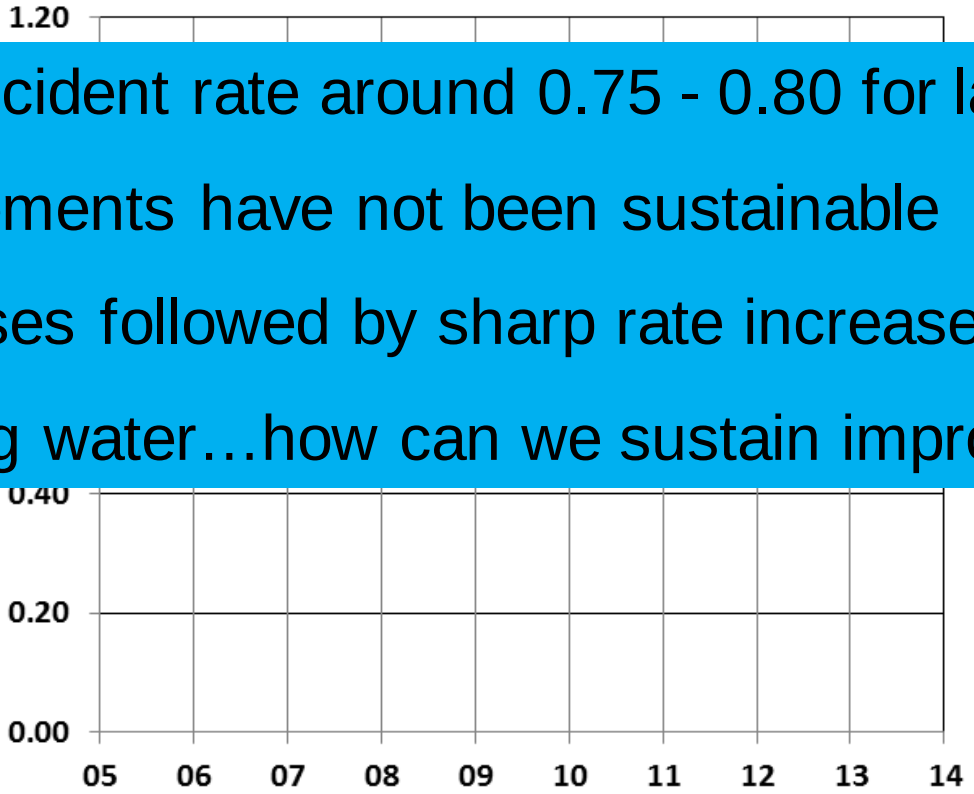
Presented By: Lee Roskop, FAA

Date: April 2015

Federal Aviation Administration


Caution · Carrying Political Promises
INTAKE
DUMP

Estimated U.S. Rotorcraft Fatal Accident Rates Per 100,000 hours – 10 Year Look Back



- Fatal accident rate around 0.75 - 0.80 for last 10 years
- Improvements have not been sustainable
- Decreases followed by sharp rate increases
- Treading water…how can we sustain improvement?

Historic rotorcraft flight hours extracted from FAA's General Aviation and Part 135 Activity Survey. Years 11 & 14 based on FAA's FY2015-2035 Forecast.

Where should we start in learning more about fatal accidents?

- **Post Crash Fire (PCF)**
  - IHST data
    - PCF was most frequently cited Sub-Occurrence Category for U.S. fatal accidents in IHST's early analysis work.
  - True effect not well understood
    - Often unclear from investigative reports whether PCF was contributory to fatalities or just present in the accident.
  - High interest area
    - Investigative authorities, regulatory authorities, and public.

FAA Collaborative Study Initiated

- **Rotorcraft Directorate**
  - Standards Staff
  - Safety Management Group

- **Civil Aerospace Medical Institute (CAMI)**
  - CAMI Autopsy Program Team
  - Medical Case Research Physician
  - CAMI Biostatistician

Approach to Study

- **5 years of data available**
  - 10/13/2008 to 9/27/2013

- **Criteria for inclusion in the data set**
  - U.S. Registered
  - Type Certificated Rotorcraft
  - Fatal Accidents

- **Autopsy results available from CAMI for review**
  - Pilot
  - Passengers, if pilot certificated

Quantity of Data

- **NTSB records that met criteria for inclusion**
  - 125 fatal accidents from 10/13/08 to 9/27/13

- **CAMI's autopsy data accounted for 78% of NTSB records (97 of 125 fatal accidents)**
  - For the remaining 28 NTSB records, CAMI does not collect autopsies for cases where:
    - Aircraft was U.S. registered but operating outside the U.S. (19 cases in this study)
    - The pilot was not fatally injured (9 cases in this study)

Analysis method

- **Initial analysis by the Rotorcraft Directorate**
  - Used autopsy data to assess the following:
    - Did a post crash fire (PCF) occur?
    - If PCF was present, did it contribute to a fatality?

- **Subsequent review**
  - CAMI's Medical Research Team – Medical Case Review Physician
  - Directorate incorporated all CAMI's recommended changes

- **Organization of results**
  - By Certification Basis
  - By Make/Model
  - Compliance with 14 CFR 27/29.952

Description of 14 CFR 27/29.952

- **Subject: Fuel system crash resistance**
  - Effective 11/2/1994
  - Amendment 27-30 (Part 27) and Amendment 29-35 (Part 29)

- **Rule addresses:**
  - Drop test requirements
  - Fuel tank load factors
  - Fuel line self-sealing breakaway couplings
  - Frangible or deformable structural attachments
  - Separation of fuel and ignition sources
  - Other basic mechanical criteria
  - Rigid or semirigid fuel tanks

Conclusions

- **Crash resistant fuel systems:**
  - **Decrease the occurrence of PCF**

	Certification Basis	
	Part 27 WITHOUT crash resistant fuel system	Part 27 WITH crash resistant fuel system
% of Fatal Accidents where PCF present	39% (30/76)	9% (1/11)

Conclusions (continued)

- **Crash resistant fuel systems:**
  - Decrease the occurrence of PCF
  - **Decrease deaths attributable to PCF**

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	Certification Basis	
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% of Fatal Accidents where PCF present	39% (30/76)	9% (1/11)
If PCF present, % of Fatal Accidents where:		
PCF contributed to fatality	20% (6/30)	0% (0/1)

Conclusions (continued)

- **When PCF occurred, cause of death was typically:**
  - Blunt force trauma rather than thermal injuries

	Certification Basis	
	Part 27 WITHOUT crash resistant fuel system	Part 27 WITH crash resistant fuel system
If PCF present, % of Fatal Accidents where:		
PCF contributed to fatality	20% (6/30)	0% (0/1)
Blunt force trauma contributed to fatality	80% (24/30)	100% (1/1)

Conclusions (continued)

For Part 27 rotorcraft without a crash resistant fuel system (CRFS), the PCF data *did not suggest significant differences* for the individual models that provided the largest sample of data.

- **84% of data for Part 27 rotorcraft without a CRFS came from:**
  - 6 different models across 4 different OEMS
- **Same 6 models account for 50% of U.S. rotorcraft fleet (as of 2015)**
- **PCF data showed comparable rates of:**
  - PCF occurrence
  - PCF as contributory to the fatalities

The data suggested *blunt force trauma* is the bigger concern in fatal rotorcraft accidents, even in cases of post crash fire…

…but what were the *specific* blunt force injuries that were documented in the fatal accidents?

Past and Present Research

- **Baseline data: Taneja & Wiegmann study**
  - Published April 2003
  - Data from 74 fatal helicopter accidents, 1993-1999
  - Injuries classified by body region/organ system

- **Data used for comparison**
  - Civil Aerospace Medical Institute autopsy data
  - Data from 97 fatal helicopter accidents, 2008-2013
  - Classified data using injury categories from Taneja and Wiegmann study

Limitations

- **The level of detail for blunt force injuries documented in autopsy reports varies by U.S. state and by individual examiner.**

- **Could not narrow cause of death to one specific blunt force injury in each accident.**
  - Even in cases where injuries were well detailed, overall cause of death is typically listed as multiple blunt force injuries.

Approach to Study

- **Similar to Post Crash Fire Study**
  - Reviewed autopsies from each case
  - Made note of each injury documented

- **Categorized injuries according to Taneja & Wiegmann's classification method**
  - Two broad classifications:
    - Bony Injuries
    - Organ/Visceral Injuries
  - Many sub-categories under two broad classifications

Approach to Study (continued)

- **Analysis via statistical comparison**
  - Goal of identifying if statistically significant differences existed between corresponding injury categories documented in the 2014 study and the 2003 Taneja & Wiegmann study.
  - Used the following statistical methods:
    - Chi Squared Analysis using $p < .05$ as measure of significance
    - Fisher's exact test for limited cases where Chi Squared Analysis was not appropriate
    - 95% confidence interval calculations

Validation of Results

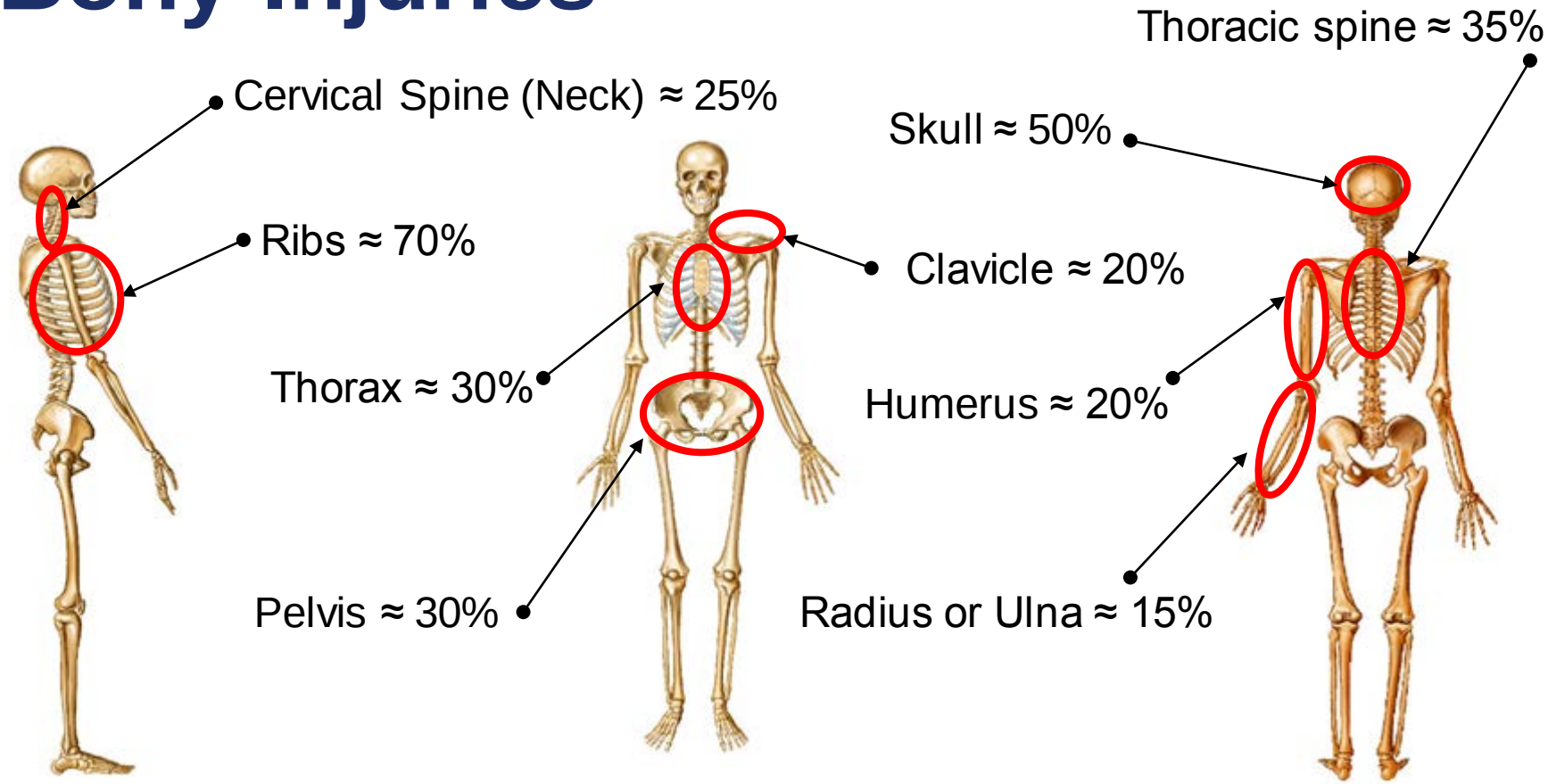
- **Autopsy analysis**
  - Reviewed, corrected, and final concurrence by CAMI's Medical Research Physician

- **Statistical analysis**
  - CAMI Biostatistician
    - Recommended appropriate statistical tests
    - Accomplished chi squared analysis and Fisher's exact test
    - Validated all results
  - CAMI Medical Research Physician
    - Reviewed all results

Results

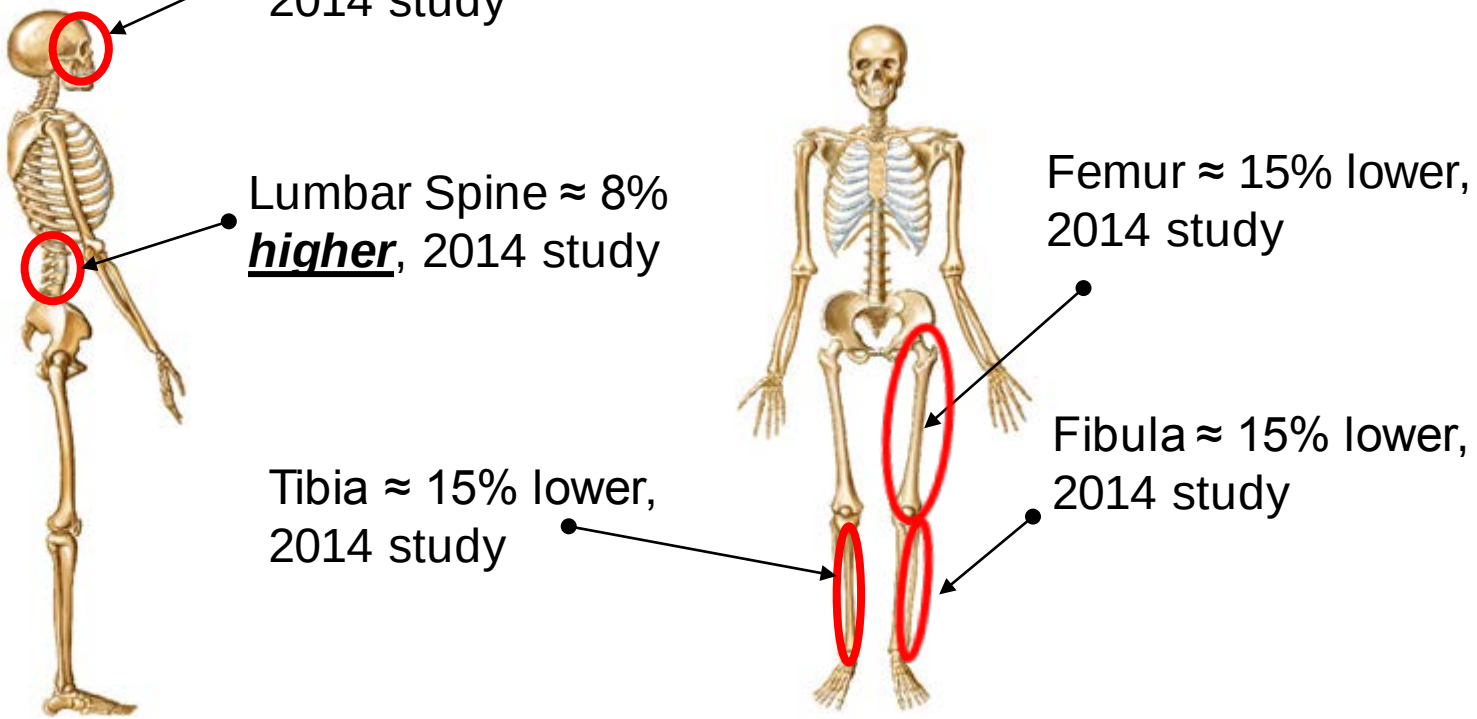
- **No statistically significant difference between the 2014 study and the 2003 Taneja & Wiegmann study for:**
  - 9 of 14 categories of bony injuries
  - 7 of 7 categories of organ/visceral injuries

Bony Injuries



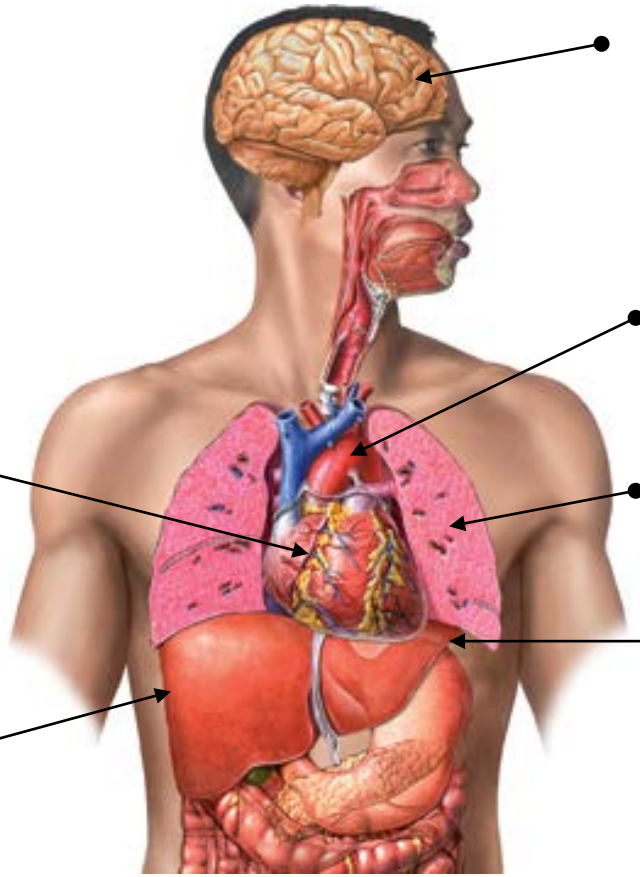
No statistically significant difference in data for bony injuries documented in these areas

Bony Injuries



Statistically significant difference in data for bony injuries documented in these areas

Organ/Visceral Injuries



Brain ≈ 65%

Aorta ≈ 35%

Heart ≈ 40%

Lung ≈ 55%

Spleen ≈ 32%
(not visible in diagram)

Liver ≈ 45%

Bladder ≈ 9%
(not visible in diagram)

No statistically significant difference in data for organ injuries documented in these areas

Further considerations

- **For the rotorcraft with a certification basis after 2003, were there significant differences in fatal injury patterns?**
  - The Taneja & Wiegmann study was published in 2003.
  - Theoretically, data on fatal injuries patterns could have been applied toward certification efforts after 2003.

- **Answer: A reasonable comparison was not feasible due to a small sample of data with a certification basis after 2003.**
  - Only 2 out of 97 fatal accidents in the study involved rotorcraft with a certification basis after 2003.

Further considerations (continued)

- **Did significant differences exist for rotorcraft involved in fatal accidents that were compliant with 27.562 or 29.562?**

- **Before answering that, a brief description of 27.562 and 29.562 is needed.**
  - Rules address Emergency landing dynamic conditions
  - Effective12/13/1989
  - Amendment 27-25 (Part 27) and Amendment 29-29 (Part 29)

Description of 14 CFR 27/29.562

- **Rule addresses dynamic (crash impact) tests:**
  - Prescribes use of 170 lb test dummy or equivalent
  - Sets specific angular, velocity, and deceleration parameters for dynamic testing
  - Requires specific performance during impact for:
    - Seating device system
    - Location of shoulder harness strap or straps
    - Location of safety belt
    - Head avoiding impact or not exceeding prescribed head injury criteria
    - Max loads to the upper torso
    - Max loads between pelvic and lumbar column

Further considerations (continued)

- **So…Did significant differences exist for rotorcraft involved in fatal accidents that were compliant with 27.562 or 29.562?**

- **Answer: A reasonable comparison was not feasible due to only a small sample of data complying with 27.562 or 29.562.**
  - Only 5 of 97 (5%) of rotorcraft in the data set complied.

- **The sample was found to be representative of low overall compliance with the 562 rule for the U.S. rotorcraft population.**
  - About 10% compliance with 27.562 or 29.562 as of 2014.
  - Rule effective in December,1989.
  - Will take 250 years to reach 100% compliance if current pace is projected forward.

Is this what the rule makers expected?

- **In 25 years (1989-2014) since the effective date of the 27/29.562 rule:**
  - ≈ 4,200 rotorcraft accidents with ≈ 9,000 total occupants
  - Only **2%** of the rotorcraft involved in those accidents were 27/29.562 compliant
  - What about the other **98%** of rotorcraft that were not compliant with 27/29.562 in those accidents?
    - ≈ 8,800 occupants
    - None were afforded the additional dynamic crashworthiness protective equipage of the 562 rule
    - Over 1,300 of those occupants were fatally injured

Further considerations (continued)

- **Could analysis by date manufactured be accomplished?**
  - Yes: Feasible, but provides much less valuable information.
  - Even if manufactured after 2003, may still have a certification basis date many years (perhaps decades) prior to 2003.

- **Divided the fatal accident data from 2008-2013 into two groups**
  1) Rotorcraft manufactured in 2003 or prior to 2003
  2) Rotorcraft manufactured after 2003

- **Compared each group to Taneja & Wiegmann study**
  - No significant difference for either group across nearly all injury categories.

- **Compared each group against each other**
  - No significant difference from each other across any injury category.

Blunt Force Injury Study Summary

- **10 years after the Taneja and Wiegmann study…**
  - No statistically significant difference for most documented bony injuries and organ/visceral injuries in fatal U.S. rotorcraft accidents.

Questions to Think About

- **Do you know the certification basis of your helicopter, to include its crashworthiness features?**
- **Does it influence how you fly your helicopter?**
- **In fatal rotorcraft accidents, skull injuries are cited in 50% of cases and brain injuries in 65% of cases.**

Knowing this, do you wear a helmet?

Questions to Think About (continued)

- **What improvements to crashworthiness or survivability equipment can decrease injuries and reduce fatal accidents? Are any possible for retrofit?**

- **Airbag technology?**

- **What measures should be emphasized, actively pursued, or identified for regulatory activity?**

Project Contributors

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