

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



Federal Aviation
Administration

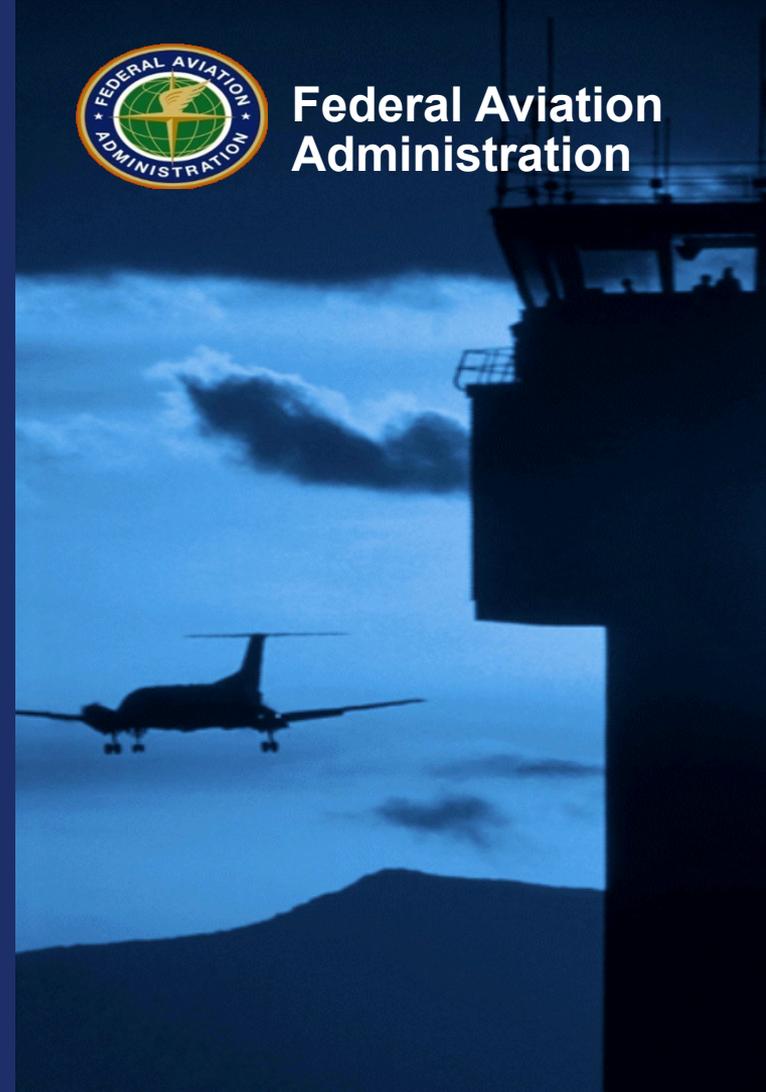


An FAA Collaborative Project:

Rotorcraft Directorate and Civil Aerospace Medical Institute (CAMI)

Presented By: Lee Roskop, FAA

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Disclosure Information

88th Annual Scientific Meeting

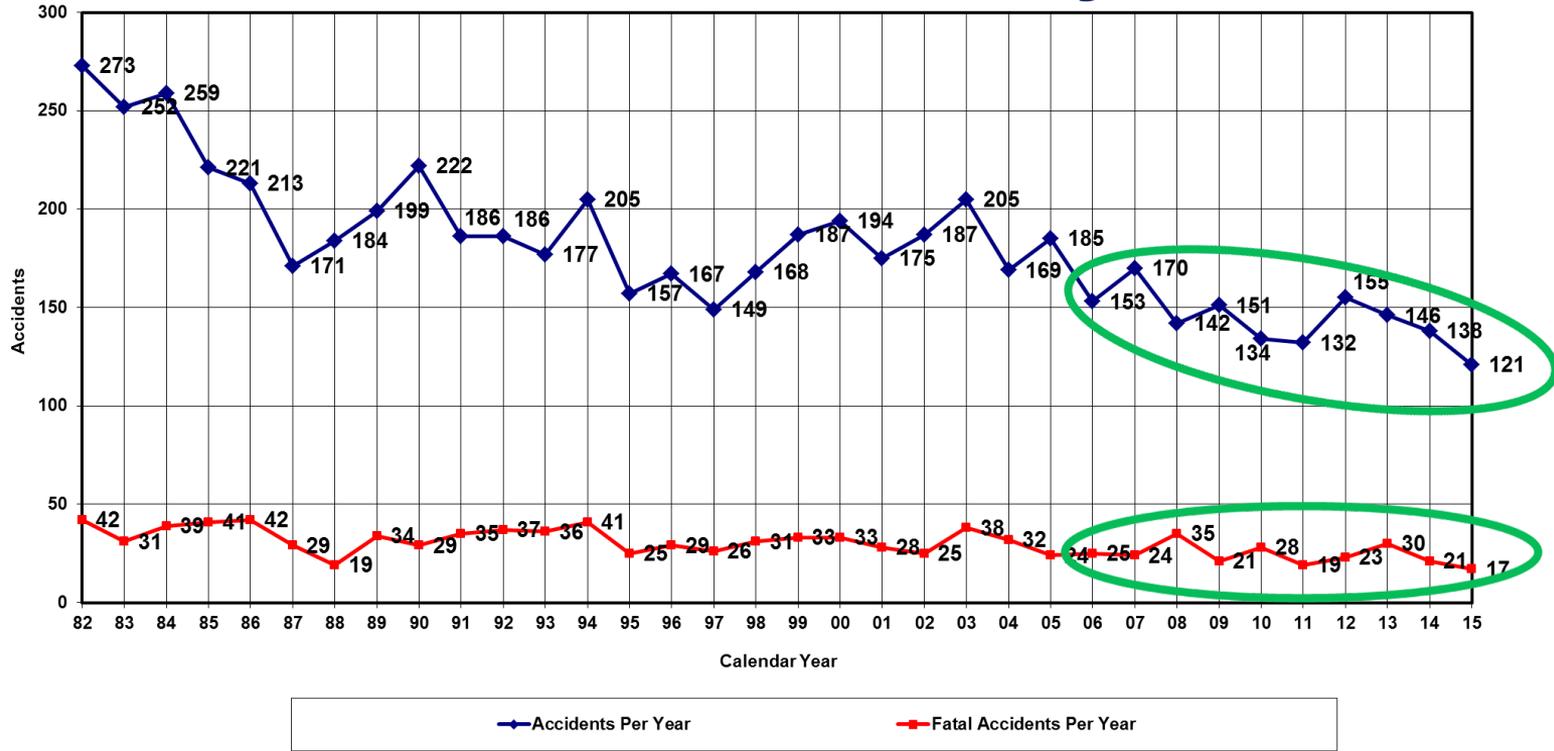
Lee Roskop, FAA

I have no financial relationships to disclose.

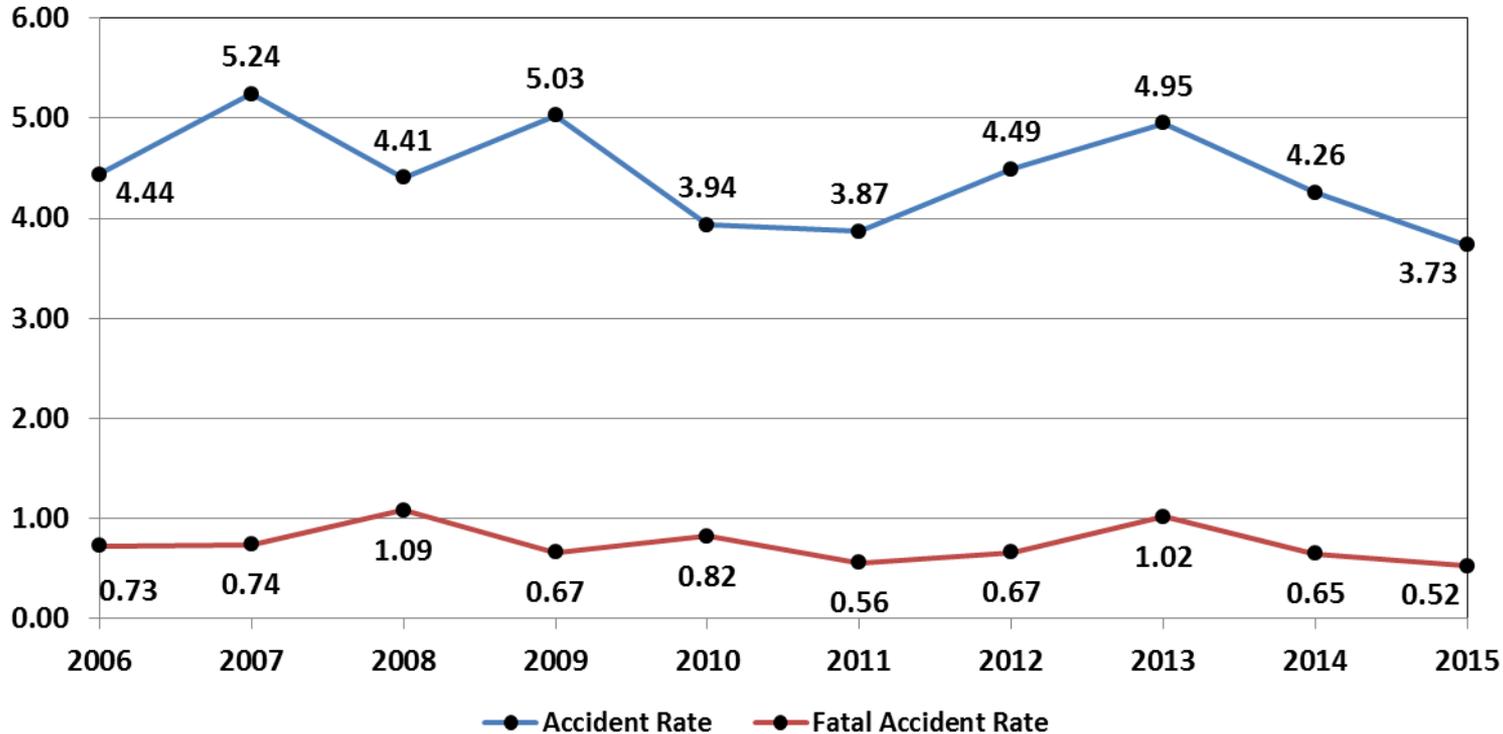
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U.S. Rotorcraft Accidents: 34 Year History



U.S. Rotorcraft Accident Rates: Recent 10 Year History



Accidents:

16% reduction
from 2006

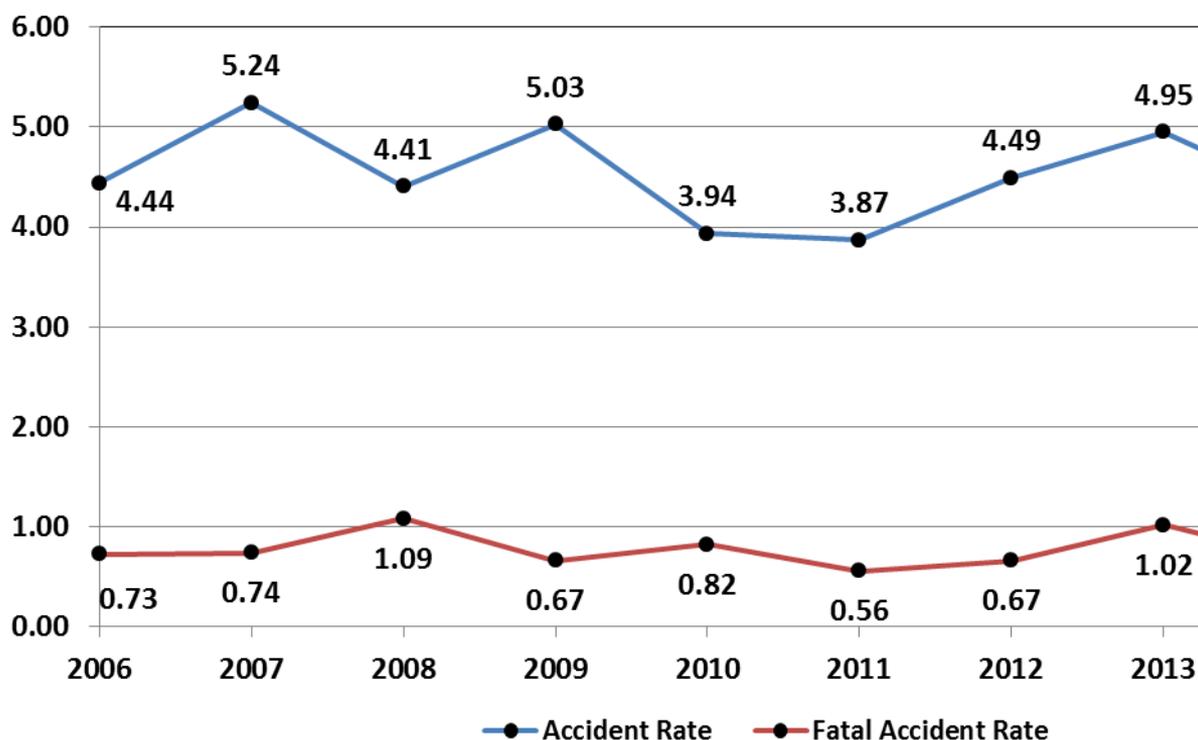
Fatal Accidents:

29% reduction
from 2006

Rates shown are per 100,000 flight hours



U.S. Rotorcraft Accident Rates: Recent 8 Year History



Rates shown are per 100,000 flight hours

Accidents:

16% reduction
from 2006

**11% increase
from 06-13**

Fatal Accidents:

29% reduction
from 2006

**40% increase
from 06-13**



U.S. Rotorcraft Fatal Accident Rate



Fatal Accidents:

29% reduction
from 2006

40% increase
from 2006

Fatal accident rate shows year over year increase two separate times.
Volatility with no sustained improvement.

426 Fatalities, 2006-13



Areas That Required Further Study

- **Post Crash Fire (PCF)**

- High interest area for investigative authorities, regulators, and the general public
- Often unclear from investigative reports how often PCF occurred and how often it contributed to fatalities

- **Blunt Force Trauma (BFT)**

- Does it play less of a role than PCF in fatal accidents?
- Are there specific fatal injury patterns we should be paying closer attention to?



FAA Collaborative Study Initiated

- **Rotorcraft Directorate (RD)**
 - Standards Staff
 - Safety Management Group
- **Civil Aerospace Medical Institute (CAMI)**
 - CAMI Autopsy Program Team
 - Medical Case Research Physician
 - CAMI Biostatistician
- **CAMI's cause of death data allowed more meaningful, accurate analysis than any previous analysis efforts.**



Data Driven Analysis Process

- **Ensured sufficient mass of data for credible study**
 - 5 years of fatal rotorcraft accident data was available (Oct 2008 – Sep 2013)
 - U.S. registered, type certificated a/c (no amateur builds included)
 - CAMI had autopsy data available for 97 of 125 fatal accidents (78%)
- **Vetted analysis through multiple levels**
 - Autopsy records compiled by CAMI's Autopsy Program Team
 - Initial autopsy review & cause of death analysis by RD
 - Subsequent review by CAMI's Medical Case Review Physician
 - Statistical analysis oversight/review by CAMI's Biostatistician
 - Organization of final results by RD
 - Conclusions finalized based on joint RD/CAMI discussion



Initial Study (2013): Post-Crash Fire (PCF) Focus

- **Two key elements studied:**
 1. Frequency PCF occurred
 2. Frequency PCF contributed to fatality

- **Organized results by:**
 - Certification basis (Part 27 or Part 29)
 - 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	
	<u>WITHOUT</u> crash resistant fuel system	<u>WITH</u> crash resistant fuel system
% of Fatal Accidents where PCF present	40% (34/86)	9% (1/11)



Conclusions (continued)

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

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If PCF present, % of Fatal Accidents where:		
PCF contributed to fatality	24% (8/34)	0% (0/1)



Conclusions (continued)

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

	Certification Basis	
	<u>WITHOUT</u> crash resistant fuel system	<u>WITH</u> crash resistant fuel system
If PCF present, % of Fatal Accidents where:		
PCF contributed to fatality	24% (8/34)	0% (0/1)
Blunt force trauma contributed to fatality	76% (26/34)	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 accounted for 50% of entire U.S. rotorcraft fleet
- PCF data showed comparable rates of:
 - PCF occurrence
 - PCF as contributory to the fatalities



Is this what the rule makers expected?

- **23 years (1994-2017) since the 27/29.952 rule:**
 - ≈ 15% compliance among U.S. rotorcraft (2017).
 - Some OEMs have made incremental improvements.
 - Enhanced fuel system crash resistance without full compliance to the 27/29.952 rule



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

Blunt Force Trauma was the cause of death in:

- 92% of all fatal rotorcraft accidents studied
- 76% of fatal rotorcraft accidents without a CRFS when a PCF occurred

So, what were the ***specific*** blunt force injuries that were documented in the fatal accidents?



Follow-up Study (2014): Blunt Force Trauma Focus

- **Used past research on fatal injuries as baseline data**
 - Taneja & Wiegmann (2003)
 - Studied 74 fatal helicopter accidents, 1993-1999
 - Classified injuries in fatal accidents by body region/organ system
- **Our Question:**
 - Were there any statistically significant differences between corresponding injury categories from Taneja & Wiegmann's 2003 study when compared to more recent data?
- **RD/CAMI used same 97 fatal accidents from previous PCF study**
 - Categorized the injuries using Taneja & Wiegmann's methodology

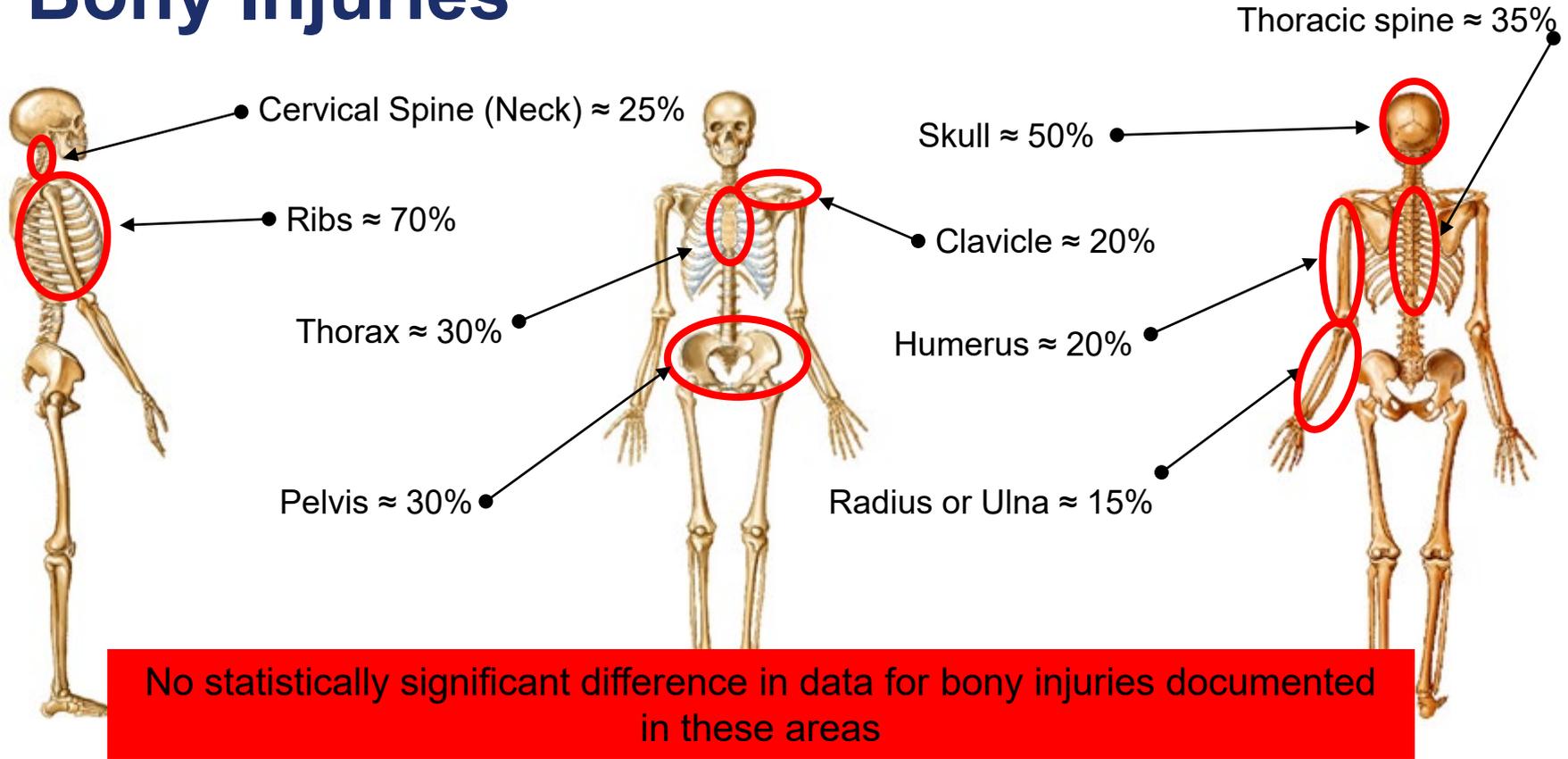


Results

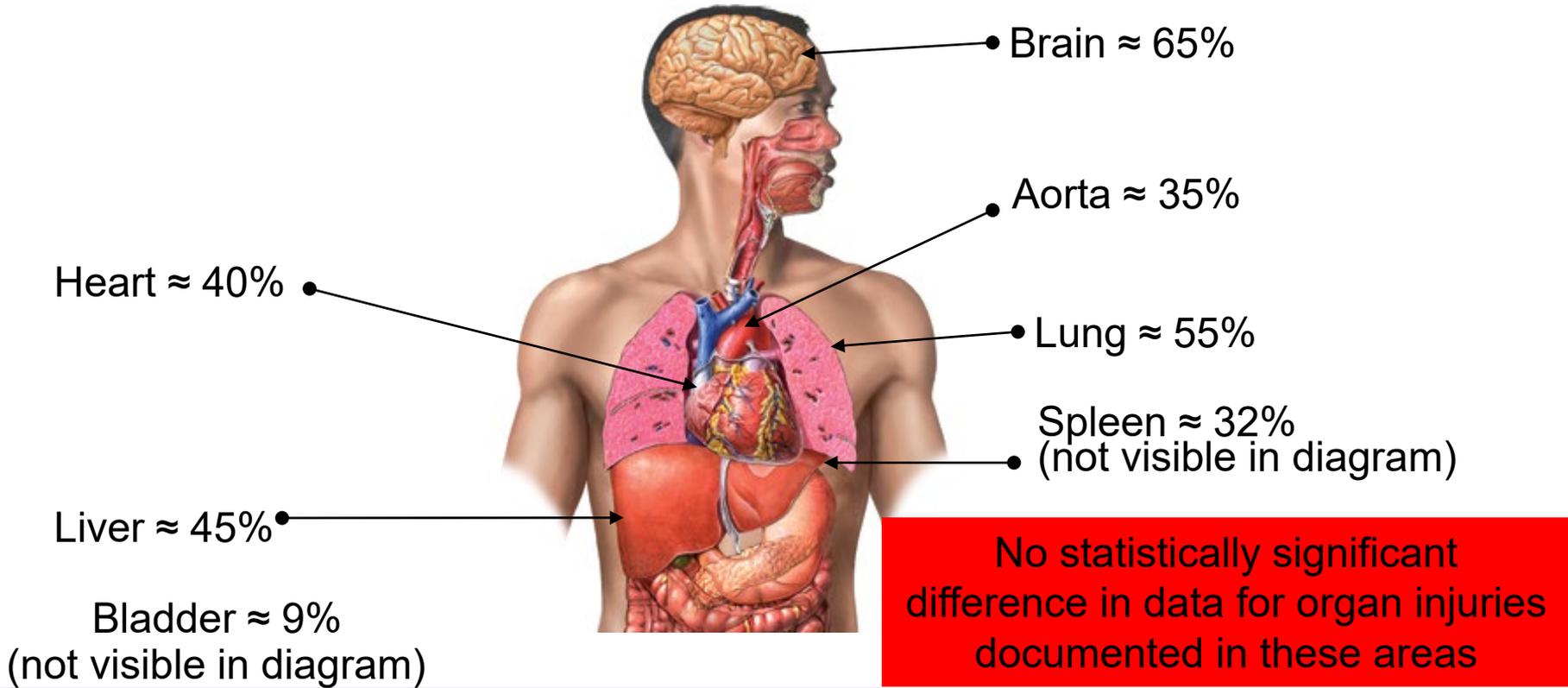
- **No statistically significant difference between the 2014 study and the 2003 Taneja & Wiegmann study for:**
 - 9 of 14 categories of bony injuries
 - 7 of 7 categories of organ/visceral injuries



Bony Injuries



Organ/Visceral Injuries



Further considerations

- **Did significant differences exist for rotorcraft involved in fatal accidents that were compliant with 27/29.562?**
- **Before answering that, a brief description of 27/29.562 is needed.**
 - Rules address Emergency landing dynamic conditions
 - Effective 12/13/1989
 - 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 27/29.562?**
- **Answer: A reasonable comparison was not feasible due to only a small sample of data complying with 27/29.562.**
 - Only 5 of 97 (5%) of rotorcraft in the data set complied.
- **Potential good news?**
 - May mean the 27/29.562 rule was successful and compliant rotorcraft were involved in fewer fatal accidents.
- **Potential bad news?**
 - May mean the data sample was representative of low overall fleet wide compliance with the 562 rule.



Further considerations (continued)

- **The sample was indicative of low overall compliance with the 562 rule for the U.S. rotorcraft population.**
 - $\approx 10\%$ compliance with 27.562 or 29.562 (2017).
 - Rule effective in December, 1989.



Is this what the rule makers expected?

- **Factors and expectations in the original xx.562 rule**
 - Based on 1979 Rotorcraft Regulatory Review Conference
 - Congress requested FAA to improve occupant protection
 - Expected 30-85% fewer fatalities/injuries (survivable accidents)
- **25 years (1989-2014) since the 27/29.562 rules:**
 - ≈ 4,200 rotorcraft accidents with ≈ 9,000 total occupants
 - Only 2% of a/c 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 equipment of the 562 rule
 - Over 1,300 of those occupants were fatally injured



Bottom Line

- **There has been a very slow incorporation of occupant protection features in rotorcraft.**
 - 15% for Crash Resistant Fuel Systems
 - 10% for Blunt Force Trauma protection
- **This has contributed to the long-term stagnancy in the rotorcraft fatal accident rate.**
- **Rotorcraft that either *were not* or *are not* required to meet the higher standard of occupant protection rules are still widely used and produced.**
- **How many lives could we save by catching actual a/c equipage up with our 20-25 year old rules?**



Key Questions for Operators

- **Do they know the certification basis of the helicopter they are operating, to include its occupant protection capability?**
- **If they are considering the purchase or lease of a particular helicopter model, does it comply with the latest occupant protection regulations?**
- **In fatal rotorcraft accidents, skull injuries were cited in 50% of the cases and brain injuries in 65% of cases. Yet, why...**

...is helmet use estimated in single digit percentages?



Project Contributors

Rotorcraft Directorate

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