Developing a Risk Index for Predicting Fatality in Aviation Crashes

Guohua Li
(GL2240@columbia.edu)

Columbia University

Collaborators

Hirut T. Gebrekristos

Susan P. Baker

Funded by R01AA09963 and R01AG13642

Background

- Most aviation crashes survivable
- Risk factors for fatality
  - Fire
  - Adverse weather
  - Location
  - Time of day
  - Type of aircraft (plane vs. copter, # of engines)
  - Not wearing safety restraints
  - Older age, male, less than 1000 total flight hours

Li & Baker 1993; 1999; Krebs et al 1995; Rostykus et al 1998;
Grabowski et al 2002; O'Hare et al 2003; Ozdogan et al 2005; Baker et al 2006

Objective

- To assess the validity of a simple risk index for predicting fatality in aviation crashes.

WHY a Risk Index for Aviation Crash Fatality?

- Tool for aviation safety research
- Risk management
- Informing safety practice and policy

FIA Score

Fire (1, yes; 0, no)

Instrument meteorological conditions (1,IMC; 0, VMC)

Away from airport (1, off-airport; 0, on-airport)

DCA06MA064

08/27/2006, Part 121 flight crashed in KY at 6:07 am outside of the airport, post-crash fire, visual weather condition, 49 fatalities and 1 serious injury.

FIA Score = 2

NYC99MA178

07/16/1999, GA crashed at 9:41pm over water 40 miles from Martha's Vineyard; VMC, no fire, 3 fatalities.

FIA Score = 1

Methods – Data Source

- National Transportation Safety Board (NTSB) aviation crash surveillance system
  - Recorded 53, 687 Aviation crashes (1983-2005)
  - Excluded aviation crashes
    - 1, 896 crashes involving gliders, balloons, blimps/dirigibles, ultra lights, gyroplanes.
    - 4, 735 crashes involving flight operations other than major airlines (14 CFR Part 121), commuters and air taxis (14 CFR Part 135), and general aviation (14 CFR Part 91).
    - 2, 228 crashes (5%) missing values on fire, IMC, crash location.
    - 11 crashes for other reasons (e.g., terrorist attacks and bomb threats)

Final study sample → 44, 828 crashes

Methods - Analysis

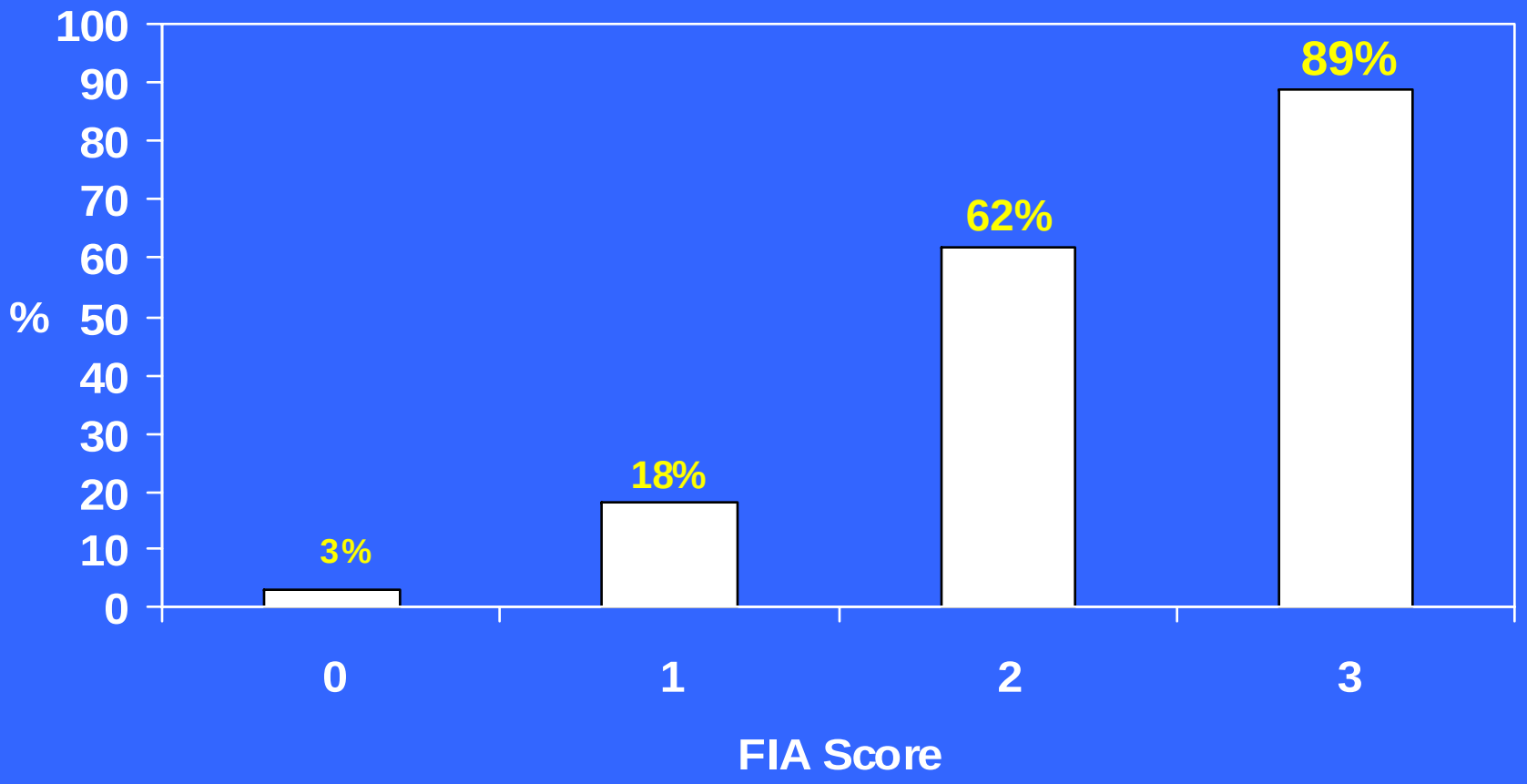
- Risk factors verification
- FIA Score
- Sensitivity & Specificity
- Area under the Receiver operating characteristics (ROC) curve
- Pilot Fatality and Any Fatality
- Different types of flight

RESULTS

Pilot Crash Fatality Rate by Flight Category

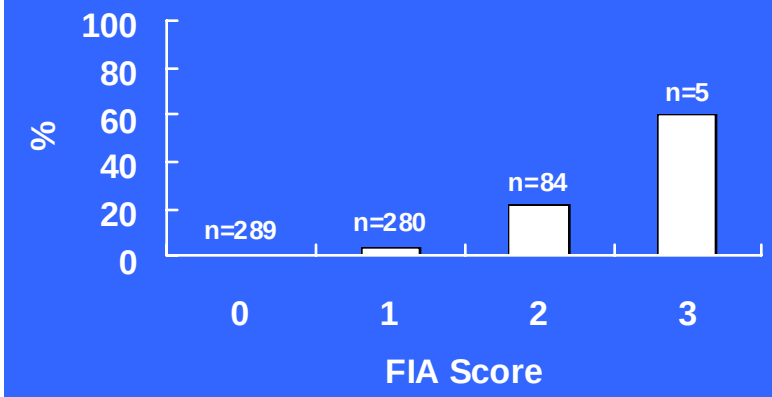
Part 121	5%
Part 135	20%
Part 91	18%
Total	18%

Pilot Crash Fatality Rate by FIA Score

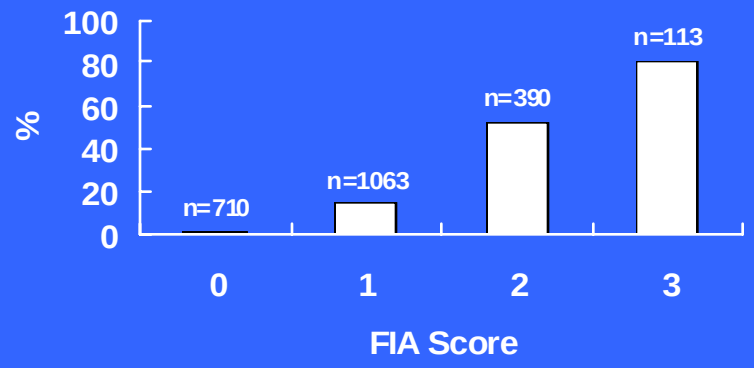


Pilot crash fatality rates by FIA score
United States, 1983-2005

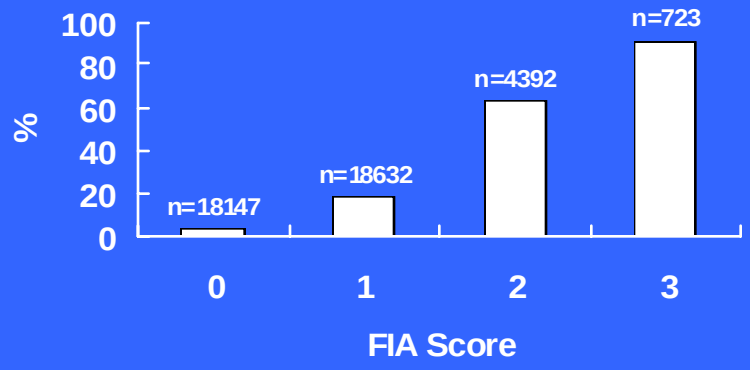
Major Airline Crashes



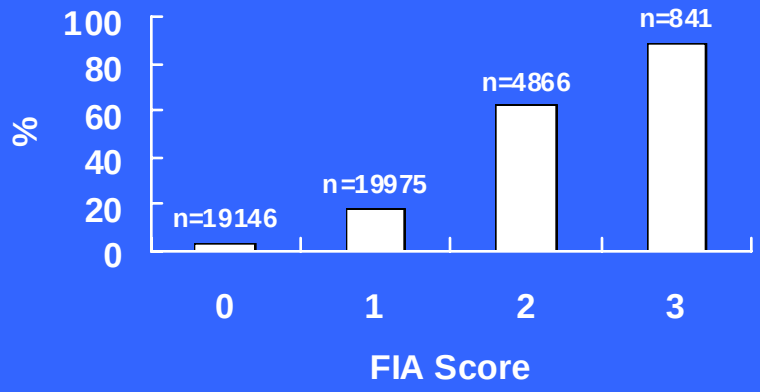
Commuter Air Taxi Crashes



General Aviation Crashes

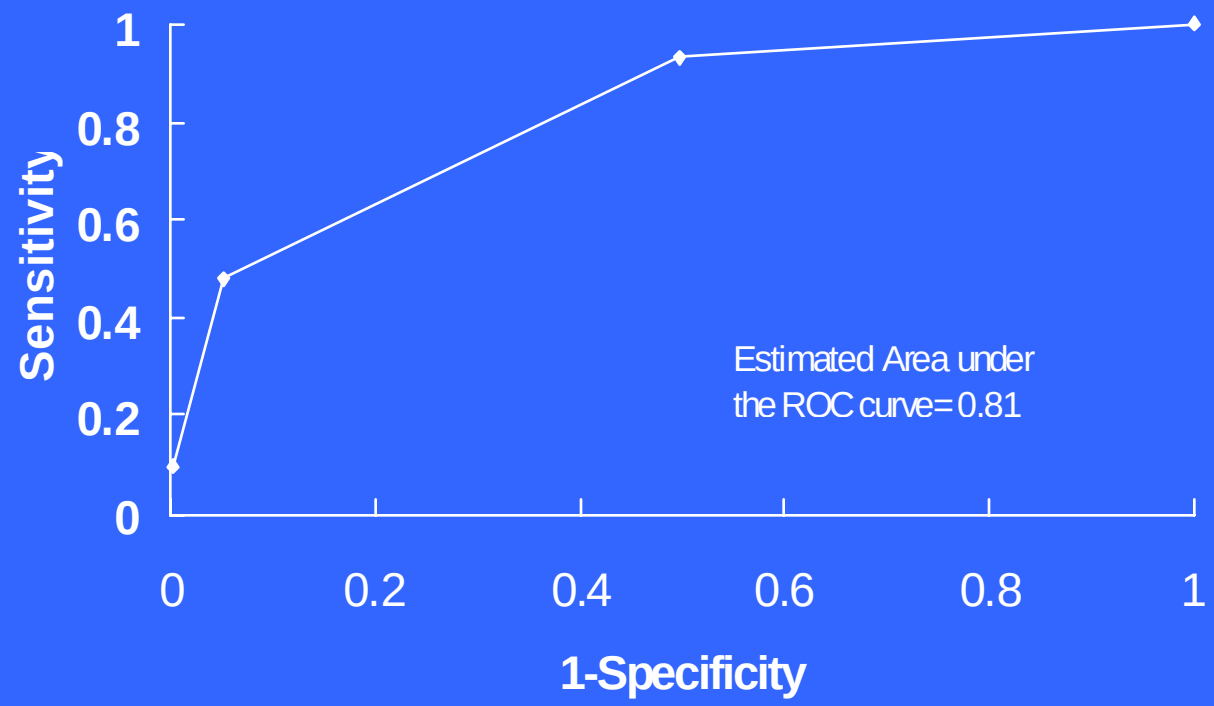


All Aviation Crashes



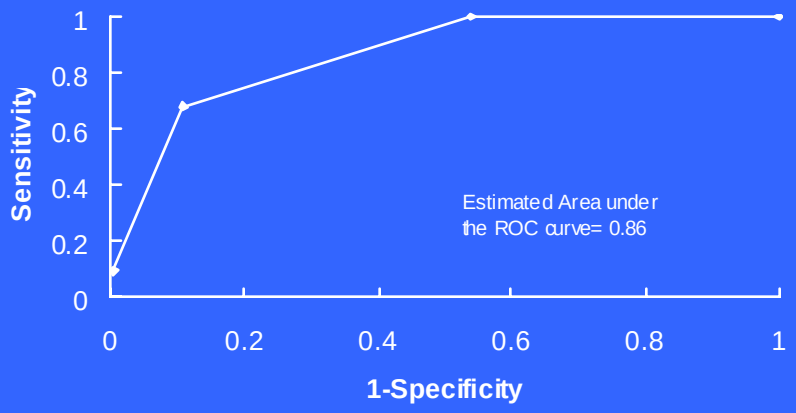
Receiver Operating Characteristic Curve

All Aviation Crashes 1983-2005

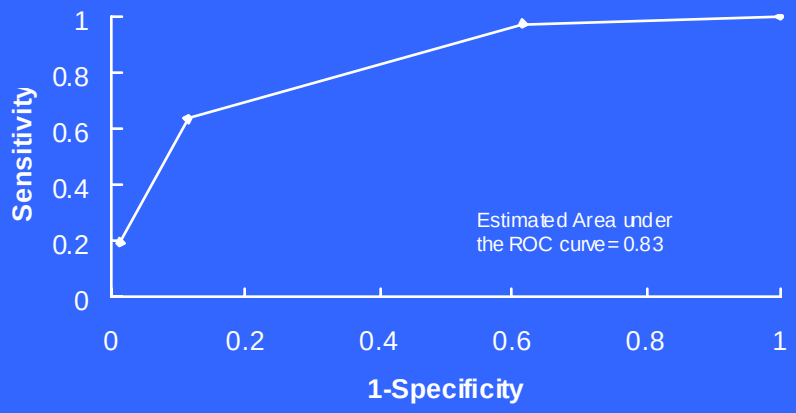


Area under the ROC curve of FIA score for predicting pilot fatality in aviation crashes

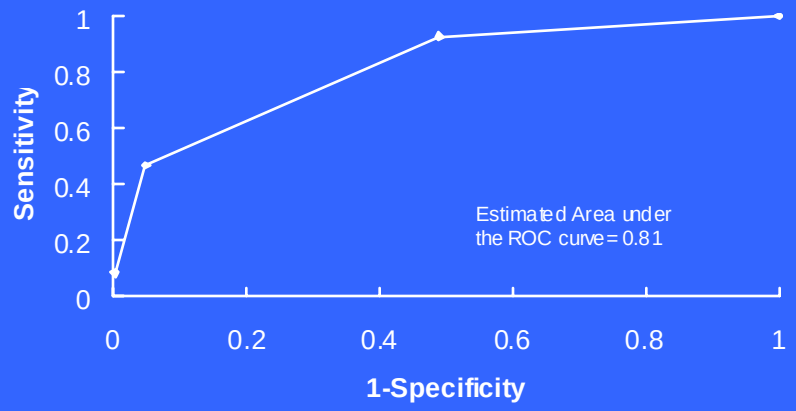
Major Airline Crashes



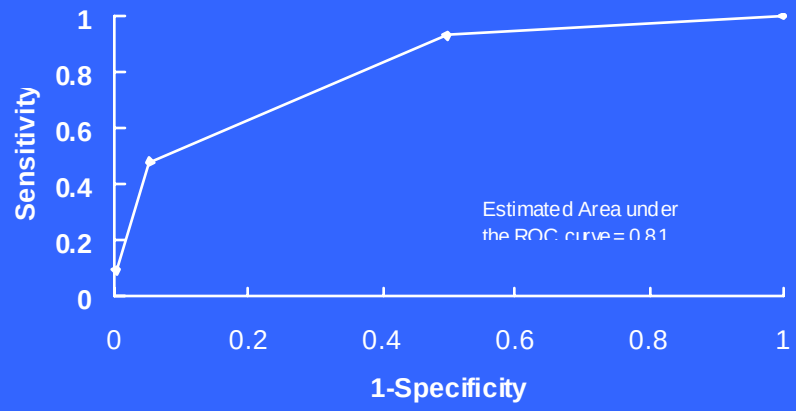
Commuter Air Taxis Crashes



General Aviation Crashes



All Aviation Crashes



Area under the ROC curve of FIA Score for predicting aviation crash fatality

Flight Operation	Pilot Fatality	Any Fatality
Marjor Airlines	0.86 (0.78, 0.95)	0.82 (0.75, 0.90)
Commuter and Air Taxis	0.83 (0.80, 0.85)	0.82 (0.79, 0.84)
General Aviation	0.82 (0.81, 0.82)	0.81 (0.81, 0.82)
Total (all parts)	0.81 (0.81, 0.82)	0.81 (0.81, 0.82)

Limitations

- Other risk factors not included
- Risk factors may change over time
- Prospective validation needed

Conclusion

- FIA score is a valid tool for measuring aviation crash fatality risk across different flight operations

Area under the ROC curve for alternative FIA scoring schemes in predicting pilot-in-command fatality

Flight Operation	4-point FIA	5-point FIA	6-point FIA
Marjor Airlines	0.86 (0.78, 0.95)	0.92 (0.85, 0.83)	0.93 (0.86, 0.99)
Commuter and Air Taxis	0.83 (0.80, 0.85)	0.84 (0.82, 0.86)	0.84 (0.82, 0.86)
General Aviation	0.82 (0.81, 0.82)	0.82 (0.81, 0.83)	0.82 (0.81, 0.82)
Total (all parts)	0.81 (0.81, 0.82)	0.82 (0.81, 0.83)	0.82 (0.81, 0.82)

How could FIA be used?

- Measure of crash severity
- Proxy of impact force
- Tool for safety program development and evaluation

Comparison of pilot-in-command and any fatality by risk factors

Risk Factors		Pilot-in-command Fatality				Any Fatality			
		Number of Crashes	Pilots Killed	CFR (%)	P-value	Number of Crashes	Persons Killed	CFR (%)	P-value
Aircraft Fire									
	Yes	4675	2880	61.6		4675	3024	64.7	
	No	40153	5009	12.5	<0.0001	40153	5508	13.7	<0.0001
Basic Weather Condition									
	Instrument	3804	2173	57.1		3804	2265	59.5	
	Visual	41024	5716	13.9	<0.0001	41024	6267	15.3	<0.0001
Location of crash									
	Away from airport	23751	6828	28.7	<0.0001	23751	7349	30.9	<0.0001
	On airport	21077	1061	5.0		21077	1183	5.6	
Total		44828	7889	17.6		44828	7889	17.6	

Pilot crash fatality rate by alternative FIA scoring schemes

FIA Score	Major Airlines			Commuters and air taxis			General Aviation			Total		
	4 Point	5 Point	6 Point	4 Point	5 Point	6 Point	4 Point	5 Point	6 Point	4 Point	5 Point	6 Point
0	0.0	0.0	0.0	1.8	1.8	1.8	2.9	2.9	2.9	2.8	2.8	2.8
1	3.6	1.7	1.7	14.6	13.1	13.1	18.2	17.2	17.2	17.8	16.8	16.8
2	21.4	7.8	3.6	52.1	38.8	40.8	64.0	52.6	62.2	62.3	50.1	58.8
3	60.0	55.2	12.8	81.4	65.4	33.3	89.6	65.4	35.0	89.3	50.2	34.0
4	na	60.0	55.2	na	81.4	65.4	na	90.7	65.4	na	89.3	65.3
5	na	na	60.0	na	na	81.4	na	na	90.7	na	na	89.3

FIA Score

- Simple composite score of aviation fatality risk factors
  - –Fire
  - –IMC
  - –Night (??)
  - –Away from Airport

METHODS-Development of FIA Score

	Death	Total Pilot in Command Crash Events	CFR (%)
Absence of ALL risk factors			
	617	19857	3.11
Presence of ONE key risk factor			
Fire	423	1233	34.31
Instrument	62	635	9.76
Airport	3501	21200	16.51
Presence of TWO key risk factors			
FI	51	98	52.04
FA	1845	3025	60.99
IA	1323	2201	60.11
Presence of THREE key risk factors			
FIA	755	828	91.18
Presence of FOUR key risk factors			
FINA	289	335	86.27

Sensitivity and specificity of FIA score for predicting pilot crash fatality

FIA Score	Major Airlines		Commuters and air taxis		General Aviation		Total	
	Sensitivity	Specificity	Sensitivity	Specificity	Sensitivity	Specificity	Sensitivity	Specificity
0	1	0	1	0	1	0	1	0
1	1	0.44	0.97	0.31	0.92	0.43	0.93	0.42
2	0.68	0.87	0.64	0.78	0.45	0.88	0.47	0.87
3	0.1	0.99	0.2	0.95	0.09	0.98	0.09	0.98