Injury Criteria for Side Impact - A Research Update

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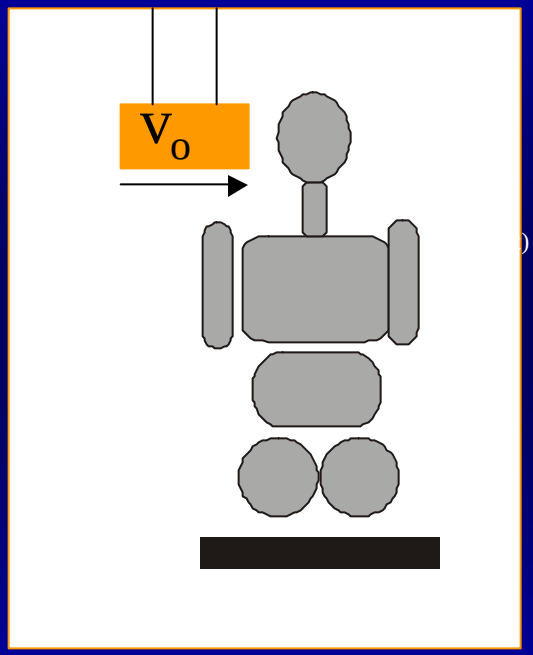
Head Injury Criteria

- Lateral head impact test data : McIntosh, et al. (1996) IRCOBI and ESV papers
- 16 tests – skull fracture and brain injury reported
- McIntosh found Ax200 (resultant head accel. Filtered to 200 Hz 3dB point) was a better predictor of injury than HIC

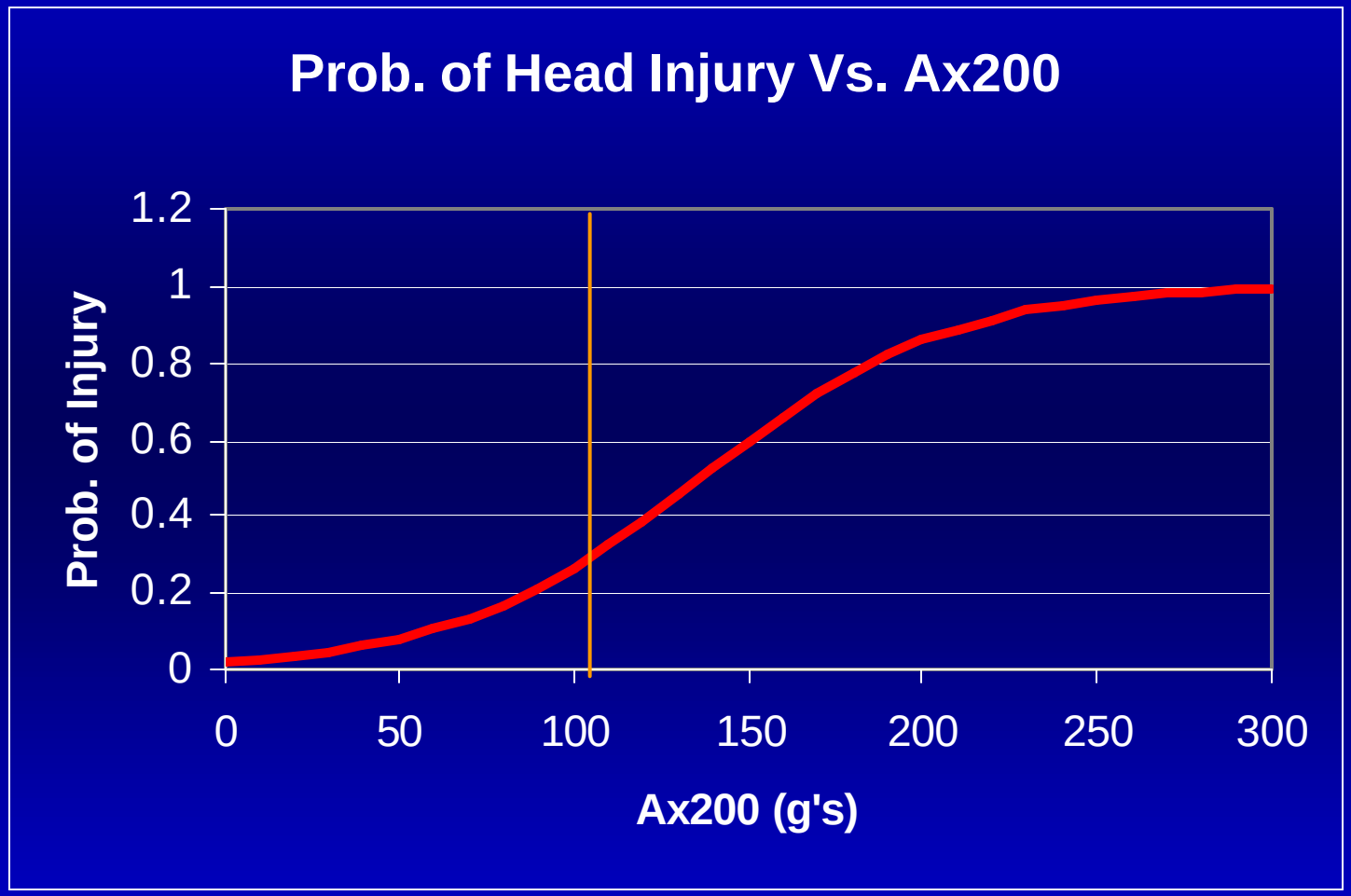


Regression Analysis of McIntosh Head Impact Data

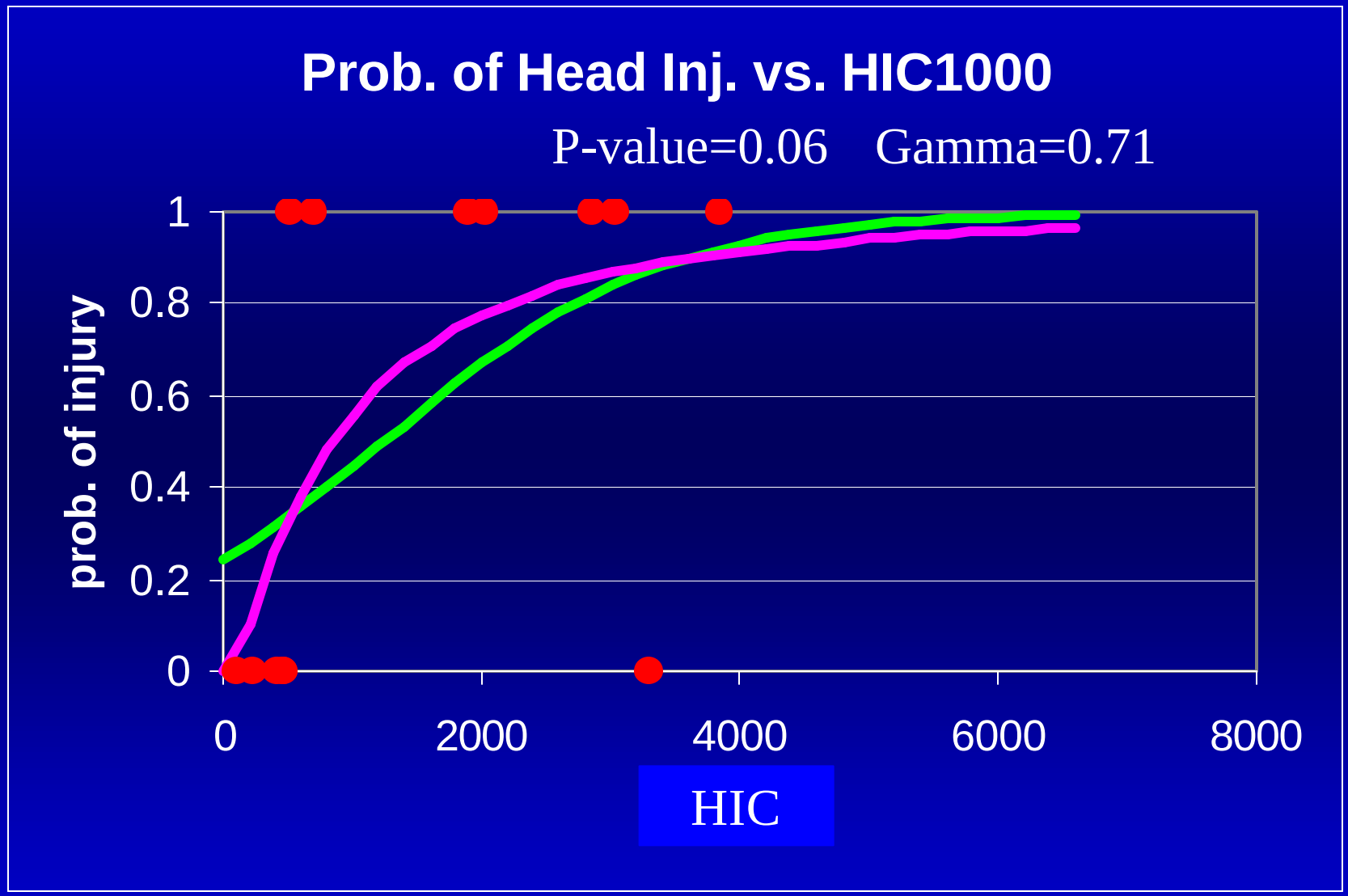
Logit of Model	n	-2logLR	-2logLR p-value	Score Chi-sq	score p-value	Gamma
2.5449-0.0535*age	13	1.671	0.1961	1.582	0.2085	0.333
-0.2231+1.3218*sex	13	1.081	0.2985	1.04	0.3077	0.262
-3.845+0.0282*Ax200	16	7.429	0.0064	6.496	0.0108	0.767
-7.2438+0.0706*3ms200	16	6.486	0.0109	5.317	0.0211	0.786
-1.6809+0.00248*HIC200	16	5.933	0.0149	4.966	0.0259	0.767
-2.2680+0.0108*Ax1000	13	4.812	0.0283	4.19	0.0407	0.714
-3.495+0.0416*3ms1000	13	2.787	0.095	2.325	0.1273	0.421
-1.1562+0.00093*HIC1000	13	3.505	0.0612	3.193	0.074	0.714

Ax200 is the discriminates injury the best

Prob. Of Injury Vs. Ax200



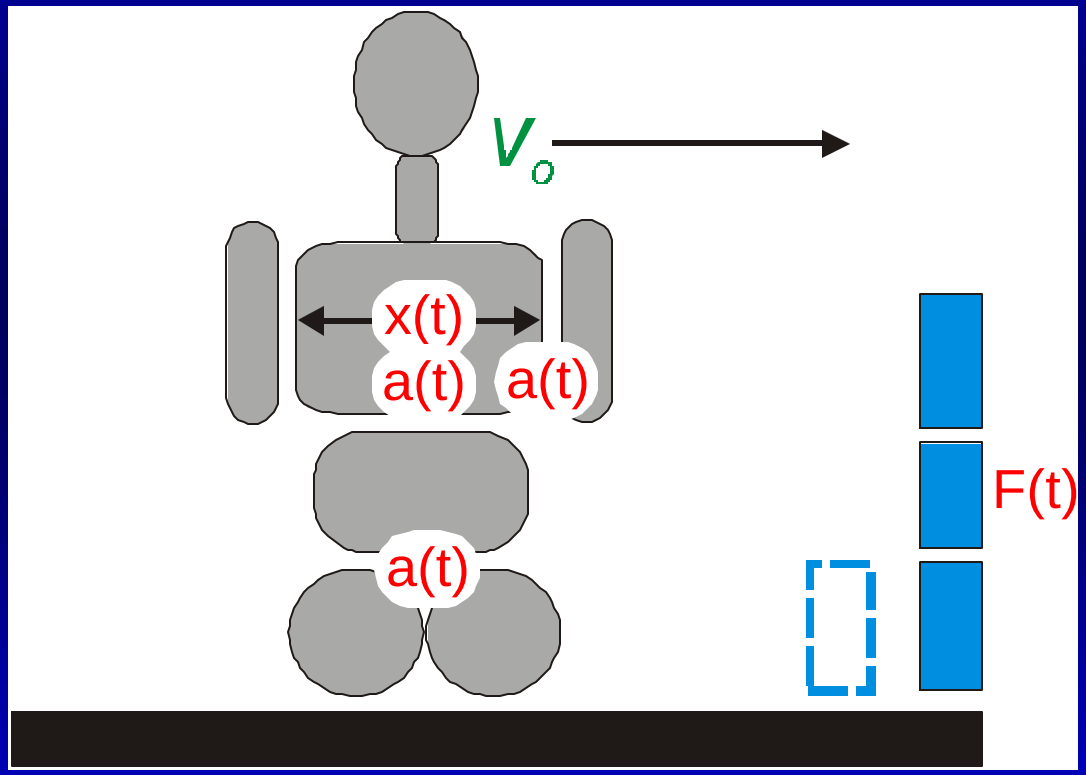
Threshold @ 25% p AIS >= 3: Ax200 ~ 102 g's


Prob. of Head Inj. vs. HIC1000
P-value=0.06 Gamma=0.71
prob. of injury
1
0.8
0.6
0.4
0.2
0
0
2000
4000
6000
8000
HIC

Thoracic Injury Criteria

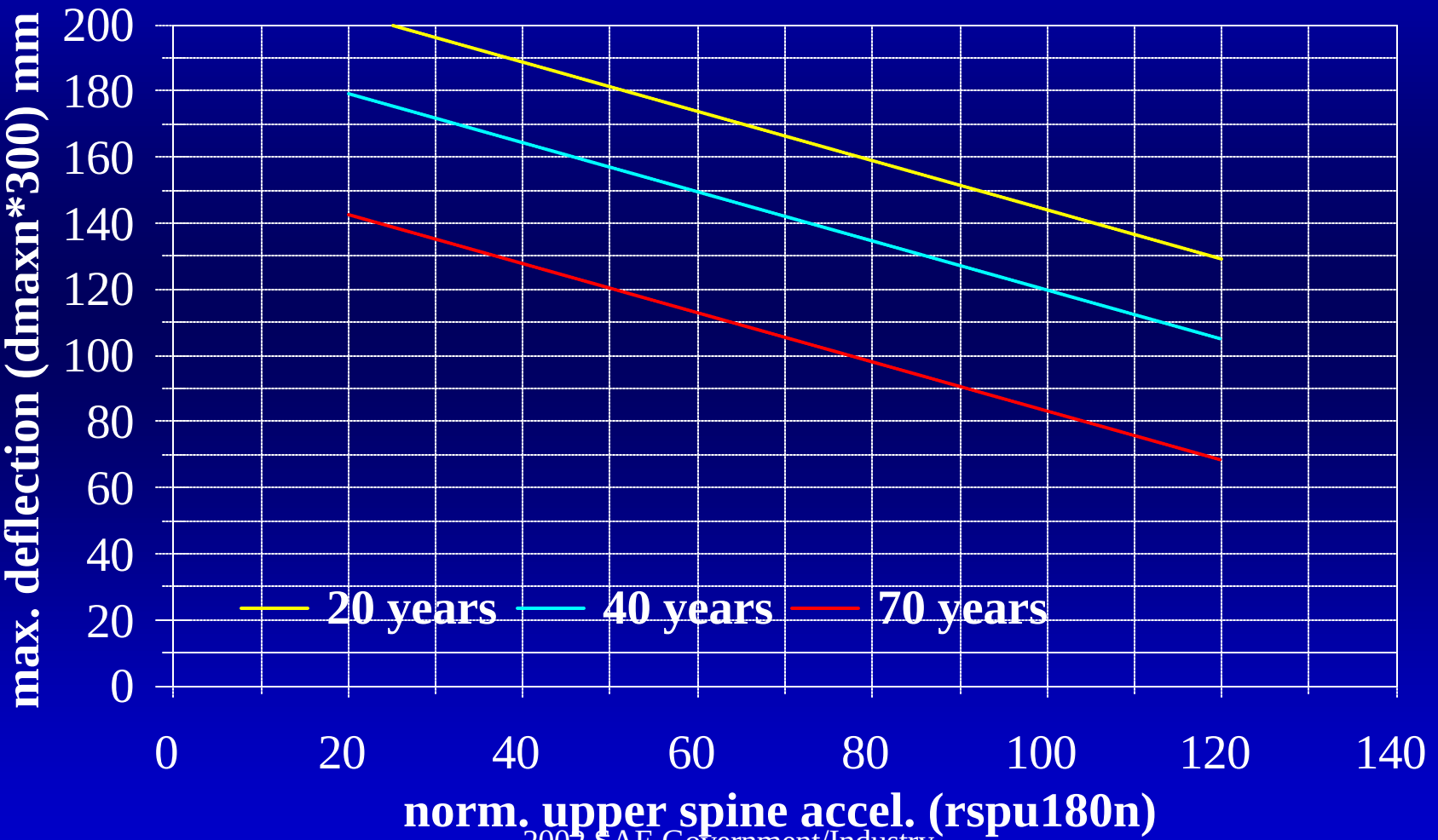
- Heidelberg type sled apparatus with left side impact.
- 42 sled tests: 15 tests at OSU, 27 tests at MCW – Of this data, 37 tests were usable.
- unembalmed fresh and frozen cadaveric human subjects: instrumented with accelerometers and chest bands.

Side Impact Sled Tests



Results using full thorax deflections

Age, maximum full thorax deflections, and resultant upper spine accelerations correlated best with injury outcome.



New Analysis Including Half Thorax Deflections

MODEL	-2logLR
Age, Max. Norm. Deflection	**26.587**
Age, Max. Norm. Lateral Spine Acc. (SAE Class 180)	21.014
Age, Max. Norm. Result. Spine Acc. (SAE Class 180)	**26.429**
ASA10	8.567
TTI	12.681
TTI* Max. Norm. Deflection	22.923
Age, Max. Norm.Defl.*Max. Norm. Result Spine Acc	**32.619**
Age, Max. Norm. Result. Spine Acc, Max. Norm. Defl.	**32.698**
Age, Max. Norm. Half Thorax Deflections	21.36
Age, Max. Norm Half Thorax Defl., Result., norm upper spine Acc.	**30.1**
Age, Max. Norm Half Thorax Defl.*Result., norm upper spine Acc.	**31.4**

Results

- Full thorax maximum deflections are better predictors of thoracic injury than half thorax deflections.
- The best injury criteria using half thorax deflections are
  - Linear comb. of age, upper spine ax., max. defl
  - Linear comb. of age, upper spine ax*max. defl
- Models normalized for age=45 years.

Injury Criteria

- Product model

  AIS 3+: Logit L= -5.5267+0.15338*Acc*Dmax

  AIS 4+: Logit L=-8.077+0.15338*Acc*Dmax

- Linear Model

  AIS3+: L= -8.4691+7.6289*Dmax+0.0646*Acc

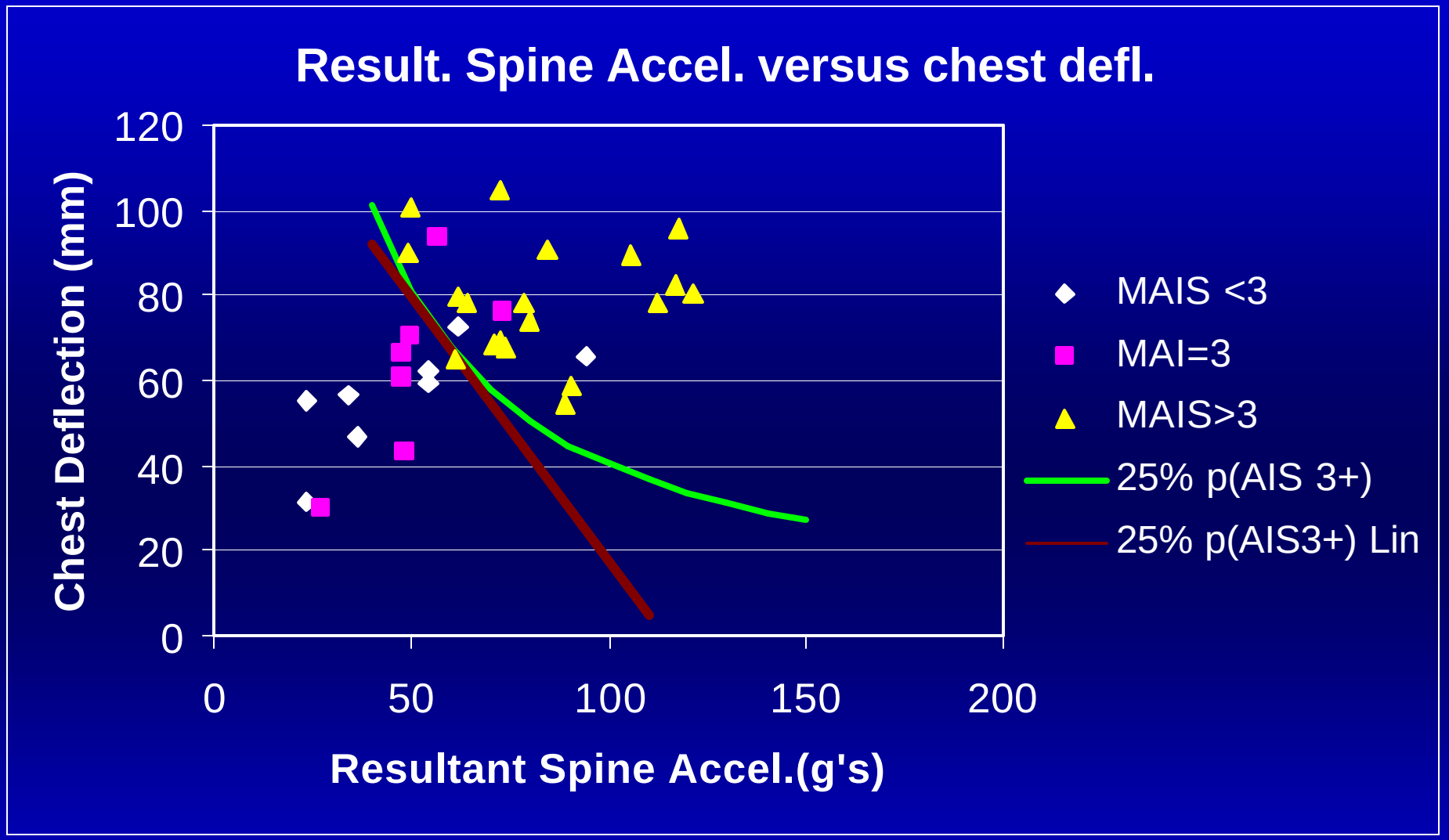
  AIS4+: L= -10.9735+7.6289*Dmax+0.0646*Acc

- Deflection Alone

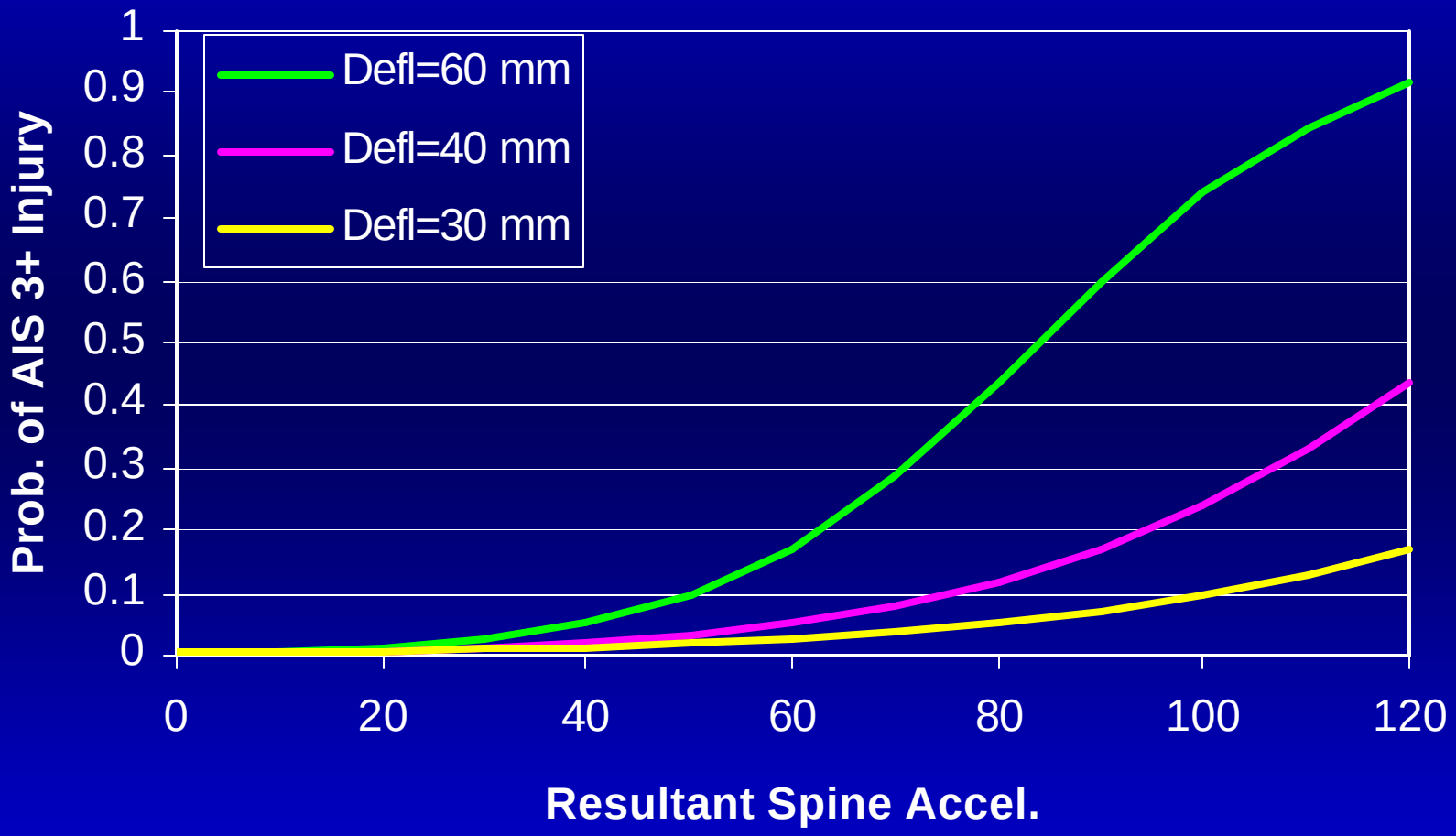
  AIS 3+: L=-2.787+0.04146*Dmax

  AIS 4+: L=-4.6697+0.04146*Dmax

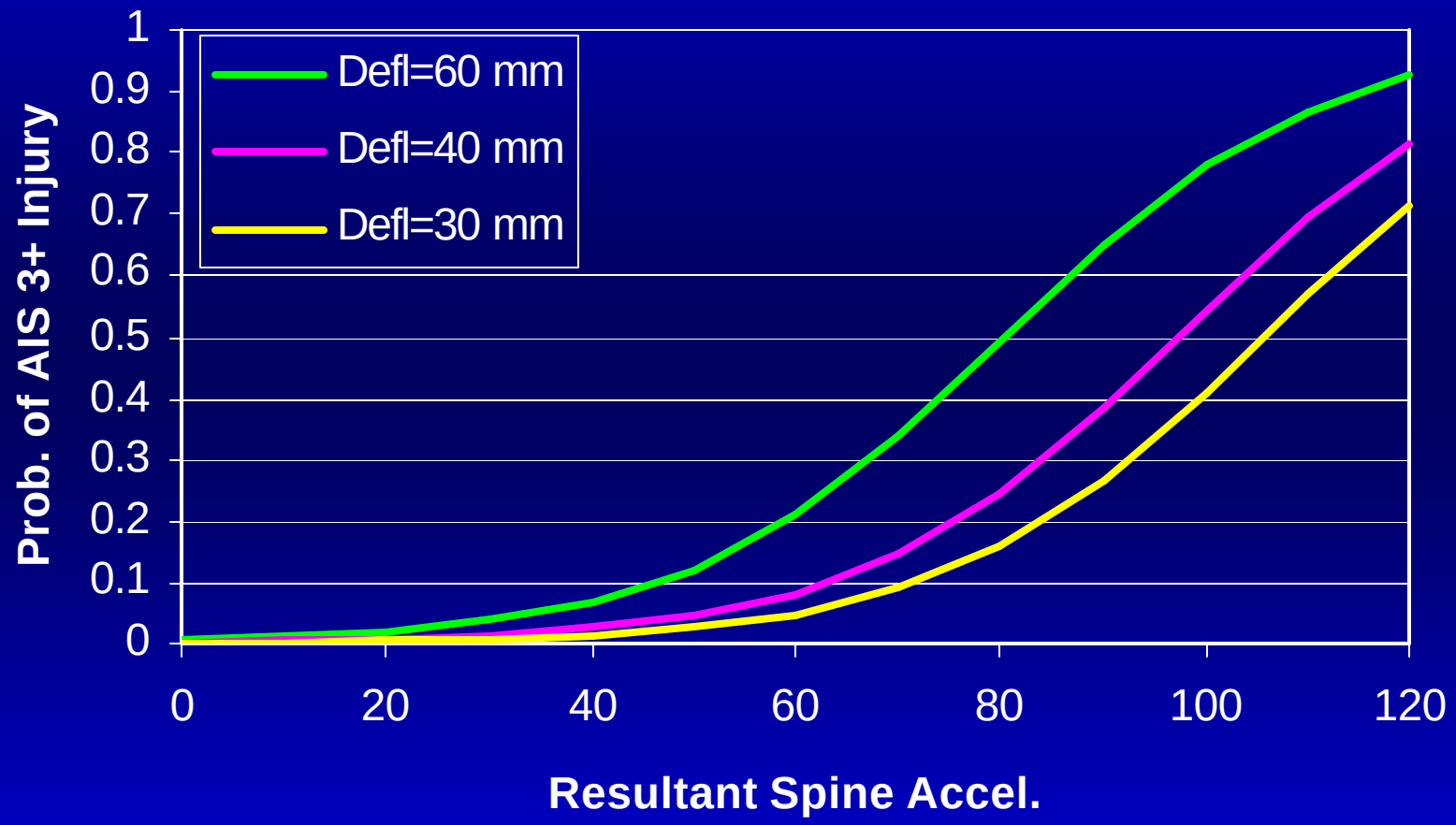
P=1/(1+exp(-L))


Result. Spine Accel. versus chest defl.
Chest Deflection (mm)
120
100
80
60
40
20
0
0
50
100
150
200
Resultant Spine Accel.(g's)
MAIS <3
MAI=3
MAIS>3
25% p(AIS 3+)
25% p(AIS3+) Lin

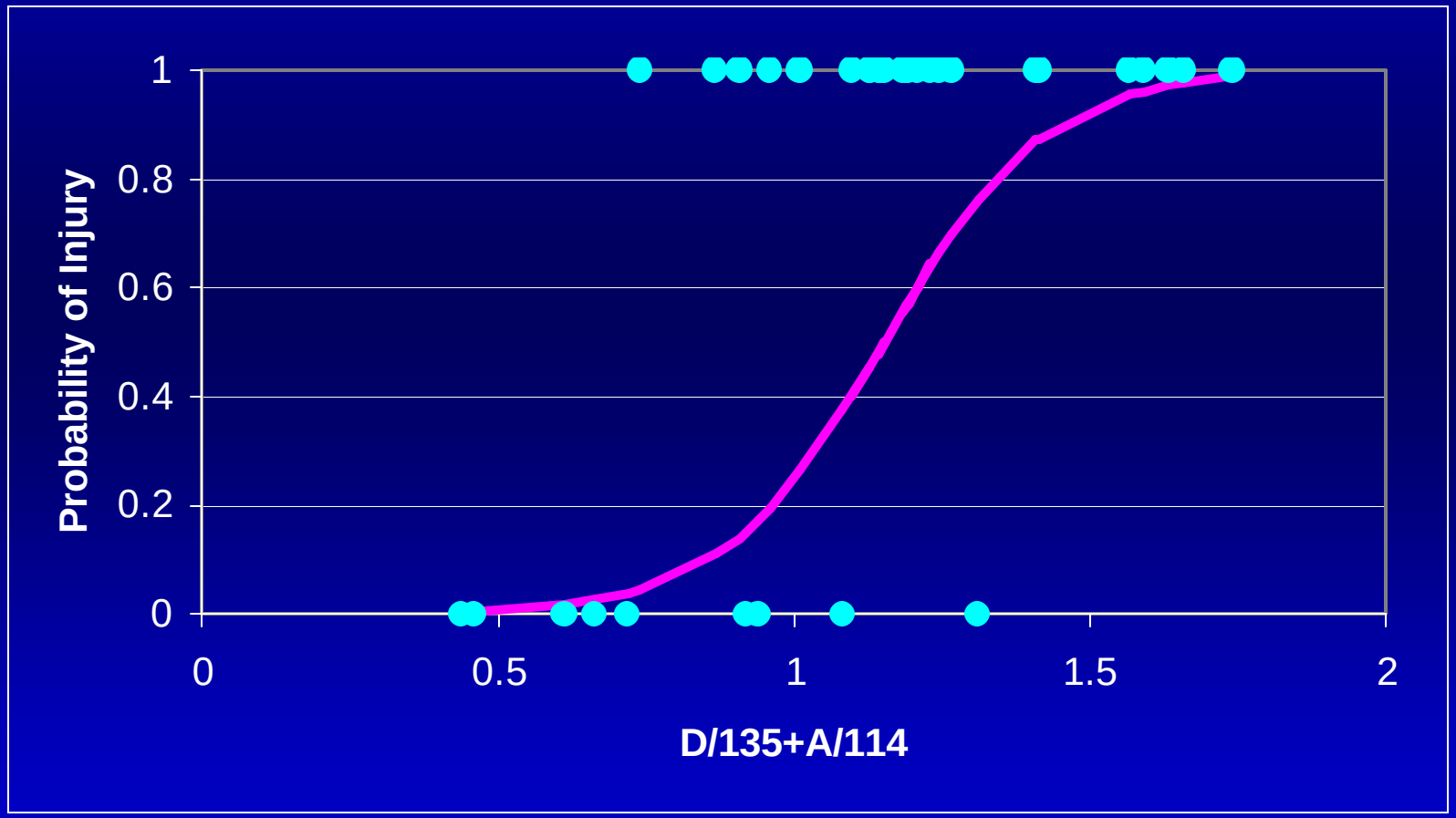
Prob. of Injury vs. spine accel (product model)



Prob. of Injury vs. spine accel (lin. Comb. Model)



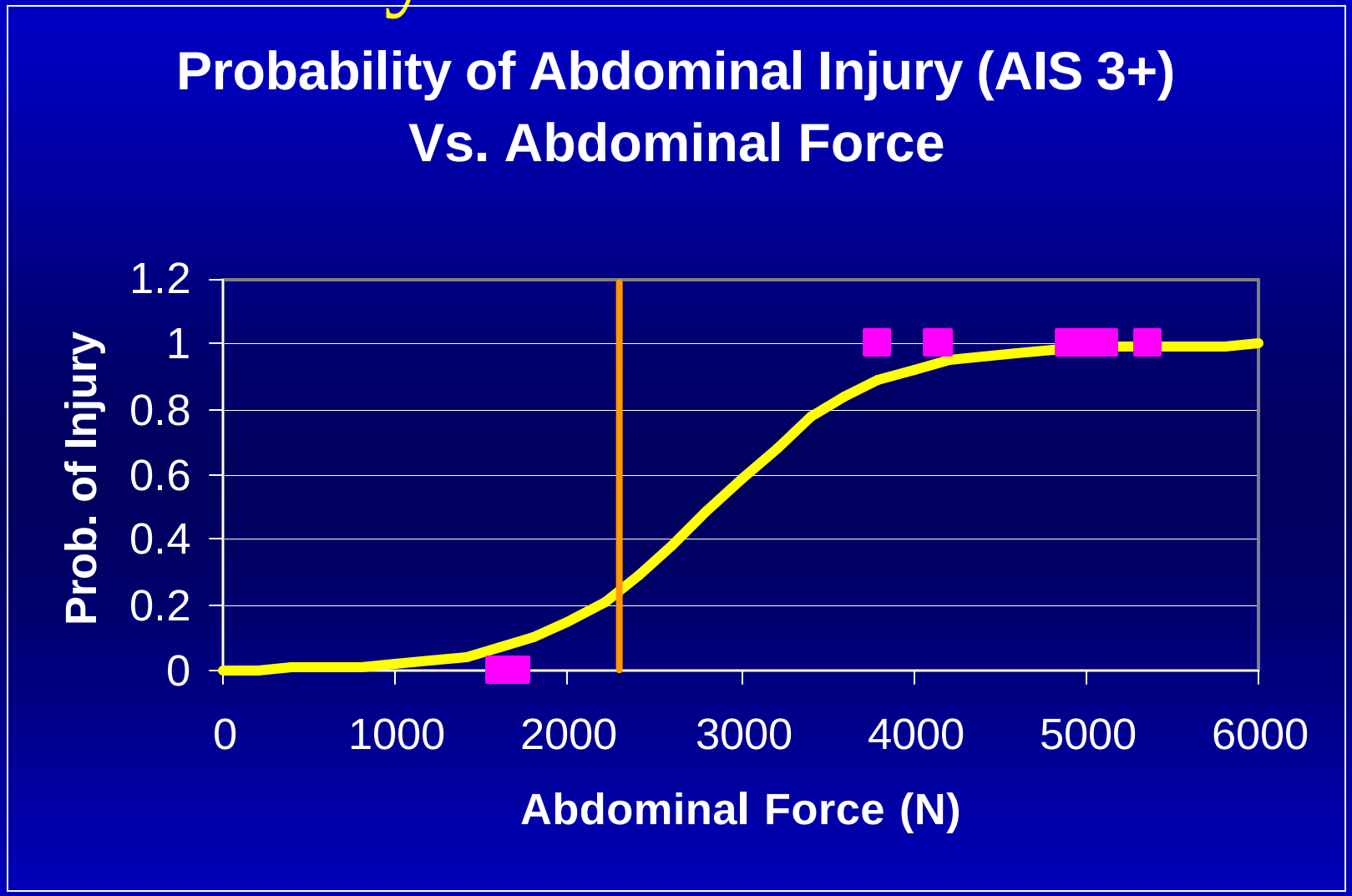
Probability of AIS 3+ Thoracic Injury Versus Linear Combination of Half Thorax deflection and Resultant Spinal Accelration



Abdominal Injury Criteria

- Human Cadaver Drop Tests – Walfisch et al. (France) : 5th IRCOBI Conference
  - 11 Cadaver drop tests onto rigid and padded armrest from a height of 1 and 2 meters.
  - Only 8 tests usable
  - ES-2 design based on these tests
  - Found threshold limit = 2500N abdominal force

Reanalysis of Walfisch Data



Threshold @ 25% p AIS >= 3: Abdominal Force ~ 2300 Newtons

Pelvis Injury

- Haffner et al (ESV 1988) reported pelvis accelerations of cadavers exposed to lateral impacts.
  - used to develop current FMVSS 214 pelvis acceleration tolerance limit
  - found that injury was dependent upon which structures in the bony pelvis were engaged by the vehicle interior

Pelvis Injury

- All current side impact dummies measure pelvis acceleration
  - presuming a biofidelic dummy acceleration response, injury threshold can be determined by relating cadaver accelerations with cadaver injury.
- Most side impact dummies offer internal force measurements
  - tolerance level can be determined by performing impacts with the dummy in the same conditions as the cadaver, and relating dummy forces to cadaver injuries.
- NTHSA is evaluating side impact data from recent sled tests, as well as data from the literature, to develop updated injury criteria.

Conclusions

- Maximum resultant head acceleration filtered at 200 Hz predicted injury better than HIC in lateral pendulum impacts.
- A combination of age, maximum normalized half-chest deflection, and maximum resultant upper spine acceleration predicted thoracic injury (mostly fractures) better than age combined with chest deflection, upper spine acceleration, ASA, or V*C.
- The maximum abdominal force threshold for 25% probability of abdominal injury is 2300 Newtons.

Injury Criteria Summary

- Sufficient new cadaver data available to develop both injury relationships and performance limits for all major body areas compatible with measurement capabilities of all three dummies.

Things to do

- Head Injury
  - Analysis of recent NHTSA sponsored lateral head drop cadaver tests.
- Thoracic Injury
  - Expand thoracic injury criteria analysis to all NHTSA cadaver test data.
  - Reanalysis of other data sources.
- Abdominal Injury
  - Reanalysis of deflection-based abdominal injury studies available in the literature for application to dummies other than the ES-2.
- Pelvis Injury
  - Review of data supporting pelvic criteria in FMVSS 214 as well as other sources (Cesari et al.)