

## HARMONISATION OF AUSTRALIAN NCAP WITH EURONCAP – LESSONS LEARNED

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### **ABSTRACT**

Australian NCAP (ANCAP) began in 1992 with full frontal 56 km/h barrier tests and added the 40% offset deformable barrier test shortly afterwards. In 1999 ANCAP decided to harmonise its testing and evaluation procedures with EuroNCAP (ENCAP). This was so ANCAP could use the results of ENCAP testing on European vehicles where the vehicle specifications were essentially similar to those of the Australian model, thereby reducing the number and cost of tests required to produce consumer information. The process has involved a joint Memorandum of Understanding, close communication between technical and management staff, auditing of ANCAP test results by ENCAP and has required very careful examination of vehicle specifications in the respective continents. Presentation of the results has been different to ENCAP based on Australian research. Training in vehicle inspection techniques to evaluate the subjective aspects of the crash test results required under ENCAP protocols has been an ongoing concern for ANCAP. The harmonisation process has been surprisingly smooth and has already benefited both groups by providing information which would not otherwise have been available. For instance, ANCAP has published consumer ratings for a range of expensive European car models which would not otherwise have been tested. There has been close liaison with the motor industry on the changes to the program. Future directions of the program will follow ENCAP in principle. The New Zealand Government and auto club joined the program in 2000 to form Australasian NCAP.

### **INTRODUCTION**

Australian NCAP (ANCAP) has now assessed fifteen vehicles under the ENCAP protocols. Eleven of these included pedestrian tests, which commenced in January 2000. This paper addresses several concerns about the ENCAP protocols which have been raised in Australia and provides constructive suggestions for changes to the protocol. Some of these concerns are

currently being addressed by ENCAP. The reference document is "ENCAP Assessment Protocol and Biomechanics Limits" by Hobbs and Gloyns, May 1999. The Insurance Institute for Highway Safety (IIHS) protocols are also used for comparison.

### **BACKGROUND**

ANCAP and ENCAP have enacted a Memorandum of Understanding which commits each partner to cooperate with the other in the production of consumer crash test information. The ANCAP Technical Committee members have been reviewing the operation of the ENCAP protocols since their adoption by ANCAP and have made representations to the ENCAP Technical Chair in relation to desired changes. Geographical separation and changes to meeting dates mean progress has been slow in reviewing and discussing the following changes.

### **FRONTAL OFFSET CRASH TEST**

#### **Scoring for chest compression**

The EuroNCAP lower limit of 22mm for chest compression (driver and passenger) may be unrealistically low. It probably does not reflect the risk of serious chest injury.

There is considerable variation between IIHS and EuroNCAP chest compression criteria. In particular the lower limit (scoring a maximum 4 points) for EuroNCAP is at 22mm whereas IIHS rates chest compression under 50mm as "good". 50mm is the *upper* limit under EuroNCAP and earns zero points. The "poor" limit for the IIHS assessment is 75mm.

An analysis of chest compression data for 184 offset crash tests (EuroNCAP, IIHS and ANCAP - see Appendix A) revealed that only two tests had a driver chest compression under 22mm (21mm in each case). The mean value was 35mm (=2 points out of 4) and the standard deviation was 7mm. This suggests that the EuroNCAP lower limit of 22mm may be too low, with less discrimination between good and bad

performers. A concern is that manufacturers may be forced to look at ways of reducing chest compression in this particular crash but it may be at the expense of greater occupant excursion or cabin intrusion and therefore greater risk of head or femur injury in other types and severity of crashes.

Ryan (1998) prepared an injury risk graph which indicates the deflection producing a 5% injury risk (AIS3 or greater) is around 45mm for the Hybrid III dummy (see Appendix A). According to Ryan a chest deflection of 22mm (10% of dummy chest diameter) produces negligible injury risk.

This analysis suggests that the IIHS criteria are more closely related to risk of serious chest injury. It has been pointed out, however, that frail occupants have a much lower tolerance to chest injury than the general population and there are grounds to adopt a more conservative lower limit. Based on existing test results a lower limit of 30mm is considered reasonable. Approximately 30% of 184 driver chest deflections were 30mm or less and approximately 17% of 111 passenger chest deflections were 30mm or less. The 50mm upper limit is considered reasonable. Less than 4% of measurements exceeded 50mm. It is recommended that the lower limit of chest compression be 30mm and the upper limit of 50mm be retained.

### **Procedures for dealing with non-airbag vehicles**

Under the protocol, vehicles without a driver's airbag cannot receive a head score more than 2 points (compared with 4 points for an airbag-equipped vehicle). For these vehicles the EuroNCAP protocol requires an additional faceform test to be conducted if the offset crash test HIC is less than 1000 *and* the head deceleration is less than 88g. The vehicle scores 2 points if the resultant peak head deceleration is less than 80g and the 3ms exceedance is less than 69g. Zero points are awarded if the honeycomb crush is 1mm or more *or* the HIC is 1000 or greater.

There are two main concerns about this system. Firstly the head injury measurements for the offset test are ignored once it is determined that a faceform test is to be conducted. In some cases in Australia a high HIC has resulted from a head impact with other than the steering wheel (usually the dash) - this highly undesirable outcome would not be a factor in the rating system. Secondly, the expense and effort needed to conduct the faceform test does not appear to be justified since, generally, the offset test HIC is high (usually just under 1000) and would result in a

very low score. In most cases the likely effect of the faceform test is therefore to introduce an opportunity for the vehicle to score better than it would based on the offset test results.

The automatic "2 point penalty" for non-airbag vehicles could be viewed as design restrictive but is considered productive in order to encourage greater take-up of airbags in countries such as Australia, where many vehicle models still have optional airbags.

This ENCAP provision is unlikely to apply in the USA or Europe where at least frontal airbags are almost universally fitted. Unfortunately many new vehicles sold in Australia still do not have airbags fitted as standard so the additional faceform test is likely to be required in Australia from time to time.

It is recommended that the faceform test be deleted and that the head score be based on the same criteria (and scaling) as the airbag-equipped vehicle, except that the maximum score is limited to 2 points.

### **Contribution of structural factors to overall rating**

In effect major structural problems such as excessive a-pillar movement and floor/sill separation are treated as penalties to be deducted from the injury score (usually chest or lower leg score). These penalties are relatively small (typically a maximum of 2 points out of an overall maximum score of 32 points for offset plus side impact tests). Generally chest and lower leg scores do not earn maximum points therefore poor structural performance may have very little influence on the overall vehicle rating. There have been several cases where a vehicle achieved relatively good injury measurements even though structural performance was very poor.

It is understood that such cases led IIHS to implement an assessment system with a separate rating for structural performance. In effect the structural rating contributes to one third of the overall rating. ANCAP adopted this approach in 1996 (Paine 1996 ). At the time there were claims of a "double penalty" arising from this approach since, in most cases, poor structural performance led to poor injury measurements but our experience is that it has worked well. In particular, it has helped to focus greater attention on structural performance, with some outstanding improvements noted by IIHS in recent years.

On the other hand, under the EuroNCAP protocol, cases have arisen where one more point (or half a point) would have enabled a vehicle to gain an extra star. Manufacturers therefore need to take into

account all modifiers, irrespective of the penalty points associated with each modifier. This situation arises because of the relatively large steps between star ratings and the importance of gaining a high star rating. It is recommended that a separate assessment for structural performance be introduced and that this assessment be included in the overall "star" rating. The assessment could be based on existing ENCAP modifiers combined with the IIHS and previous ANCAP systems.

### **Measurement and rating of dash movement**

Cases have been encountered where there is substantial rearward movement of the dash and firewall. In the more extreme cases the crash forces appear to be concentrated on the firewall with little load transferred to the roof, floorpan or vehicle sides. This results in excessive intrusion of the dash into the passenger compartment but, in some cases, little a-pillar displacement. This could contribute to injury for larger or smaller front-seat occupants or out-of-position occupants. The ENCAP protocol does not include assessment of dash movement in the rating.

Currently rearward movement of the dash is only an issue if the dash fascia rail separates from the a-pillar (one point penalty against chest score). Dash movement is measured by IIHS and ANCAP but not ENCAP. Although *steering column* movement is measured this is considered to be an inadequate indicator of a structural problem (see next item).

IIHS measures dash movement at knee level and rates the movement as follows: <50mm=good, <100mm=acceptable, <150mm=marginal, otherwise poor. These are more stringent than ANCAP values of 80mm, 150mm and 200mm respectively (measured at top of dash). IIHS and ANCAP also use the above values for rating a-pillar movement. For comparison, EuroNCAP treats a-pillar movement <100mm as good and more than 200mm as poor. Appendix B illustrates dash and a-pillar movement measurements for ANCAP and IIHS tests. It is recommended that measurement of dash movement be included in the protocol. The scoring could be based on that used for a-pillar displacement.

### **Precautions needed when rating steering column movement**

Post-crash static displacement of the steering column is measured and may contribute up to a one point penalty for the head score. However the steering column assembly usually deforms when struck by the occupant (with or without an airbag), therefore its

residual position is unlikely to reflect the situation at the height of the crash or any extra risk to occupants due to unfavourable motion of the steering column.

Dynamic motion of the steering column can be an important factor in the protection of the occupant from injury. Cases that have been observed include:

- the steering column was moving up and back at the time it was struck by the occupant, possibly doubling the impact velocity.
- the steering column moved down, allowing the occupants head to pass over the top of the steering column. In some cases the dummy head hit the dash and the throat struck the hub of the steering column. The neck is not instrumented for this unusual type of impact, which is certainly life-threatening.
- steering column movement causes the airbag to inflate in the wrong position, causing the dummy head to roll off the side of the airbag or to strike a hard object.

A further difficulty is that some steering columns have a break-away design so the final position of the steering column might not represent the dynamic situation.

Clearly it would be desirable to assess the dynamic movement of the steering column but this can be difficult, particularly when an airbag deploys. Further consideration needs to be given to this issue. In the meantime, appropriate precautionary notes should be added to the protocol.

A related issue is the method of measuring steering column displacement. The EuroNCAP protocol requires the hub (and airbag) to be removed and the end of the steering column marked and measured. This appears to be unduly complicated and time-consuming. A readily accessible point on the exterior surface of the steering column assembly should be used for this purpose.

### **Assessment of knee impact area**

The EuroNCAP protocol defines a knee contact zone based on the point of impact of the knees. This includes "an additional penetration depth of 20mm...beyond that identified as knee penetration in the test". A difficulty is that, with many modern dashboards, the point of maximum knee penetration is not readily evident. This is because the plastic dash material usually deforms or shatters.

The actual point of contact of the knees can vary due to very subtle influences. It is not possible to predict,

prior to the crash, exactly where the knee impact will occur. One reason for having "knee modifiers" is to account for situations where, by good luck, the knee just missed an injurious component. However, the current assessment method depends on this random impact point and it means that assessments might not be repeatable.

A better approach may be to define the knee impact zone based on defined conditions such as the seating reference point rather than the dynamic points occurring in a crash test.

A possible adverse effect of the knee modifiers was raised at the NCAP Symposium in Cologne in December 1999. In order to avoid the knee penalties some manufacturers appear to be removing substantial structures from behind the dash. Although this reduces the risk of knee and femur injury it is claimed that this can lead to unfavourable kinematics such as submarining. There are doubts about this claim. Also it has been pointed out that frail occupants in particular can suffer severe hip joint injury at much lower loads than those set by EuroNCAP so a situation of no knee contacts may be desirable. It is recommended that the knee impact zone be defined in terms of vehicle reference points rather than knee impact points. The possibility encouraging energy-absorbing designs through this method should be pursued.

### **Dummy entrapment**

Several IIHS and ANCAP offset tests have resulted in the driver dummy's legs being trapped by pedal or floor deformation. Assessment of entrapment is not included in the current ENCAP protocol but is included in IIHS and previous ANCAP evaluations.

Foot or leg entrapment is readily evident when the dummy is being removed from the vehicle. In some cases the leg had to be disconnected to extricate the dummy. This outcome could seriously hamper rescue efforts. A modifier based on entrapment could be applied to the lower leg score, although the injury potential involves more than just the legs. It is recommended that a modifier be developed for leg/foot entrapment.

### **Tools required to open a door**

The inability to readily open a door could hamper rescue efforts. This factor is less serious than foot entrapment because extrication can be through a window or another door. Door opening force is

measured under the current ENCAP protocol but is not a modifier.

Out of 174 offset tests evaluated (ANCAP, EuroNCAP and IIHS) there were 69 cases (40%) where tools were needed to open the driver's door. Manufacturers appear to be addressing this issue because recent models were better - tools were required in 17 (29%) out of 59 tests evaluated from 1998.

A modifier based on door opening effort could be applied to the lower leg score, although the injury potential involves more than just the legs. In any case the penalty should be less than that for entrapment of the legs. It is recommended that a modifier be developed for door opening force.

### **Footwell intrusion**

In the offset test there is a tendency for crash forces to be concentrated in the lower structure on the driver's side. A good design channels these forces away from the footwell area and avoids excessive intrusion of the footwell into the passenger compartment. Some vehicles have been observed to undergo excessive deformation of the footwell but, by good fortune, the lower leg injury measures have been low.

The EuroNCAP protocol foreshadows the introduction of a modifier for footwell intrusion. It was included in previous ANCAP evaluations.

Under previous ANCAP guidelines a footwell intrusion from 250mm to 349mm resulted in a 1 level downrating of structure. Intrusion greater than 350mm resulted in a two-level downgrading.

The ANCAP guidelines are based simply on the rearward displacement of the footwell. 6 gridpoints are marked on the footwell and the maximum rearward displacement from the 6 points is used in the assessment. IIHS rates the resultant (X, Y & Z) displacement of the footwell (and pedals) as follows: <150mm=good, <225mm=acceptable, 350mm=marginal and >=350mm poor. It is recommended that a lower leg modifier be added based on rearward displacement of the footwell.

### **Fuel leaks**

In a small number of ANCAP tests there have been three cases of major fuel leaks following an offset test. Although this type of incident is very rare it can have very serious consequences. The current

protocol does not include a modifier for fuel leaks. It was included in previous ANCAP evaluations.

Problems observed so far involved locating a fuel tank and fuel lines adjacent to rotating components (a tail shaft) and routing the exhaust pipe around the fuel tank in a manner which resulted in the pipe pushing against the fuel tank in a frontal crash (a brittle, ageing exhaust pipe is an even greater concern). It is recommended that a modifier be developed for fuel leaks.

### **Undesirable occupant kinematics**

'Unstable airbag contact' is one of several concerns about occupant kinematics. Others include partial head ejection, severe head strikes during rebound, neck twist (sometimes associated with the head rolling off the side of the airbag) and submarining. There have also been cases where airbag deployment has been too early or too late. Only airbag stability is covered under the EuroNCAP protocol. Most of the other factors affected the results under previous ANCAP (and IIHS) guidelines.

The components of an occupant restraint system need to work in unison to ensure that the crash forces are distributed to parts of the body that are best able to cope with these forces and to prevent the occupant from contacting injurious objects. An assessment based solely on injury measurements ignores the potential for injury due to unfavourable occupant kinematics. Although airbag stability (which is included in the protocol) is an important factor, others should also be taken into account. It is recommended that either the modifier 'unstable airbag contact' be expanded to include other unfavourable occupant kinematics or a new category of 'Occupant Restraint' is introduced into the rating system.

### **Restraint failures**

Cases have arisen where seat anchorages, seat backs, seat belts or doors have failed during a crash. Airbags might also fail to deploy. These issues are not covered under the current protocol. Most were covered under previous ANCAP (and IIHS) guidelines.

Although the offset crash test is a severe crash, the equipment used to restrain occupants should be able to withstand the crash forces without catastrophic failure that could greatly increase the risk of injury. It is recommended that a new category of 'Occupant

Restraint' be introduced into the rating system to include restraint system failures.

### **Life-threatening incidents that are not picked up by instruments**

There is a limit to the types of life-threatening injury that dummy instruments are able to detect. Some cases have arisen where a vulnerable part of the body received a severe impact but this did not show up in injury measurements.

Under the current protocol there is no provision for modifying the rating on the basis of unusual potentially life-threatening incidents.

Two incidents of major concern are the steering wheel impacting the dummy's throat and the brake pedal moving up and rearward and impacting the dummy's groin. Both cases have been observed in Australia. In each case the impact was considered to be life-threatening but did not result in high injury measurements in body regions that were instrumented. It is recommended that a new category of 'Occupant Restraint' be introduced into the rating system to include life-threatening incidents.

### **SIDE IMPACT CRASH TEST**

#### **High seat vehicles**

The current protocol, which uses a moving barrier, is not appropriate for high ground clearance vehicles such as many four-wheel-drives. With conventional cars the crash forces are usually spread between doors, b-pillar and sill. With small cars the barrier may miss the sill completely, resulting in extra demands on the door and b-pillar. The opposite happens with high ground-clearance vehicles, where the sill takes a significant proportion of the load. These types of vehicles are over-represented in rollover crashes and collisions with narrow objects such as trees. Therefore the pole test is considered more appropriate for these vehicles. It is recommended that high vehicles (or possibly all vehicles) be subjected to the pole test instead of the moving barrier test.

#### **Lack of modifiers for Side Impact Rating**

Currently no modifiers are applied to the side impact test. In several cases circumstances have arisen where the occupants were exposed to undue risk of injury but these hazards were not reflected in injury scores.

Concerns include excessive intrusion of b-pillar and doors, excessive folding of floor (risk of entrapment), seat integrity and exposure of sharp edges or protrusions. In one recent case the side of the dummy's head struck the exposed edge of the outer door skin with a severe impact. Due to deformation of the metal panel the head injury measurements were within limits but with a human occupant there is a risk that the sharp metal edge would have penetrated the skull. The injury risk to small people may be greater with the seat in a forward position as energy absorbing material is often placed in the door near the contact point with the dummy hip/abdomen. With the seat in a forward position the occupant might not be protected by this feature.

It is recommended that a set of modifiers be developed for the side impact test.



**Figure 1. Head strike during side impact test**



**Figure 2. Deformed door panel**

### **Design features that appear to circumvent the injury measurements**

Portions of the dummy torso and the legs are not instrumented. In theory, it is possible to design a vehicle so that most of the loads are taken by these uninstrumented regions. This could artificially

improve the score because the instrumented regions take less load.

Interior door trim that protrudes, or has local stiffening, should be examined to see if it loads uninstrumented body regions. Seats should be examined for inserts that appear to be for a similar purpose.

It is recommended that a modifier based on assessment of interior design be developed and the penalty applied to the abdomen score. The position of small and large occupants and position of design features should be considered.

### **Child restraints**

In Australia compulsory top tethers on child restraints make individual vehicle designs less important. On the basis of real world crash investigations, the head decelerations specified in the ENCAP protocol are much too low - children ride out much more severe crashes without injury provided that head excursion is controlled.

The ease of installation of the child restraint in the vehicle and the security of the installation are issues related to vehicle design. Some objective measurements could be developed to assess these issues. Other issues are dynamic intrusion of vehicle components into the child's survival space and failure of child restraint components or anchorages.

The effort, beyond that required by legislation, for informing vehicle owners about the correct installation of child restraints should form part of the assessment. For example, the provision of an informative video would be an advantage.

Assessment criteria are being developed for the performance of child restraints in Australia. These are likely to vary from those used by EuroNCAP.

### **Pedestrian impacts**

Undesirable vehicle design features may result from the method of determining the lower legform test points. This concern may also apply to upper legform and head impact tests.



**Figure 3. Underside view of 'crush can' after the offset test. There was no observable deformation of this very stiff structure.**

In one case in Australia the vehicle had a highly flexible bumper bar with two very stiff "crush cans" that were mounted at the front of the sub-frame rails and protruded into the bumper space. Because the structures are symmetrical only one could be tested under the protocol.

The vehicle scored one poor result and two good results because a second potentially injurious point could not be found. Although not intended in this case, it demonstrates a way of circumventing the intention of the protocol.

It is recommended that a modifier be added to the lower leg score if there are hazardous protrusions into the bumper space and their layout is such that a second 'injurious' impact test is avoided.

### Overall Rating

Due to the equal weight given to offset and side impact scores in the overall score and the lack of modifiers for the side impact test, vehicles can earn a 3 star rating with a very poor offset score. For example, with a "perfect score" of 16 in the side impact test, the vehicle need only earn 0.5 points in the offset test (out of 16) to reach 3 stars (16.5 points) The side impact result tends to disguise the poor offset result. A similar situation occurs when the vehicle is eligible for the optional pole test and earns 2 extra points. In this case the side impact and pole tests can add up to 18 points and the vehicle need only earn 7.5 points in the offset test to reach 4 stars.

There appear to be two options:

1. Apply a cut-off value for the offset score or
2. multiply the offset score by a set factor before it is added to the overall score.

In the first case, a minimum offset score must be reached in order to earn the star rating. A possible system is:

Stars	Frontal >= AND Frontal + Side + Pole >=	
5	-	32.5
4	10	24.5
3	6	16.5
2	2	8.5
1	-	0.5

The second column is equivalent to the current EuroNCAP system, before the overall score is rounded to an integer.

For the second option, based on the proportion of serious crashes involving frontal and side impacts, it would be appropriate for the offset score to carry twice the weight of the side impact score.

Under this proposal the star rating would be based on the formula:-

$$2 \times \text{Offset score} + \text{Side impact score}$$

In deriving proposed star breakpoints for this formula it is assumed that any vehicle that earns less than 0.5 points in the offset test cannot earn more than 1 star overall. The remaining range for offset scores is then divided into four (corresponding with 2 to 5 stars).

From this the recommended breakpoints for stars are:

STARS	2xOS+SI >=
1	1
2	16.5
3	26
4	35.5
5	45

In this case the two points from the pole test can still result in an overall rating that disguises a poor offset result.

It is recommended that the star rating system be amended to include cutoff values for the offset score.

### OTHER SAFETY ISSUES

#### Safety equipment

Efforts by manufacturers to provide safety-related equipment beyond that necessary to meet regulation requirements are not taken into account in the rating system.

The availability of safety features, as standard or optional equipment, could be assessed or reported.

OSA (Japan NCAP) publishes tables of important safety features available for each model. Such features could include: passenger airbags, side airbags, lap/sash seat belt in centre rear seat, effective head restraints for all seats, antisubmarining seat design, luggage restraint/cargo barriers, integrated child seats, automatic activation of warning flashers and ABS. It is recommended that the OSA approach of publishing tables comparing safety features available for vehicles be considered.

### Head restraint design

There is no encouragement for manufacturers to improve head restraint design beyond the minimum required to comply with regulations.

IIHS started measuring and rating head restraint design in the mid-1990s and this approach has since been adopted by the Research Committee for Automotive Repair (RCAR). In effect, to obtain a good rating the head restraint must be close to the back of the occupant's head and no lower than the head's centre-of-gravity. In 1996 ANCAP adopted the IIHS approach for its ratings. IIHS research has demonstrated a correlation between good head restraint positioning and reduced risk of neck injury.

There is still debate about the issue of neck injury and some researchers advocate a seat system performance approach rather than looking solely at head restraint positioning. This is considered desirable in the long term but, in the meantime, head restraints that offer little protection are still being fitted to vehicles. If implemented at the design stage, head restraints meeting the IIHS criteria need not cost more than the poor designs. The FIA has proposed that head restraint performance be rated. It is recommended that head restraints be rated according to RCAR criteria ([www.rcar.org](http://www.rcar.org)).

### CONCLUSIONS

While the exchange of information between ANCAP and ENCAP has been relatively efficient, the liaison in regard to evaluation protocols has suffered from geographical distance between the partners, exacerbated by the difficulty for the Australian members in travelling to Europe for EuroNCAP Technical Committee meetings. Electronic communication has been valuable for the exchange of information but has not completely substituted for regular personal meetings.

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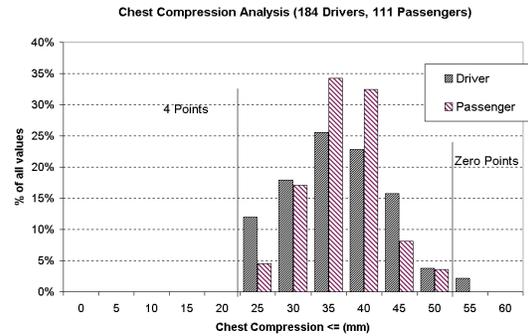


Figure 4. Results of analysis of 184 offset crash tests conducted in Australia, Europe and the USA.

Appendix A Chest Compression Analysis

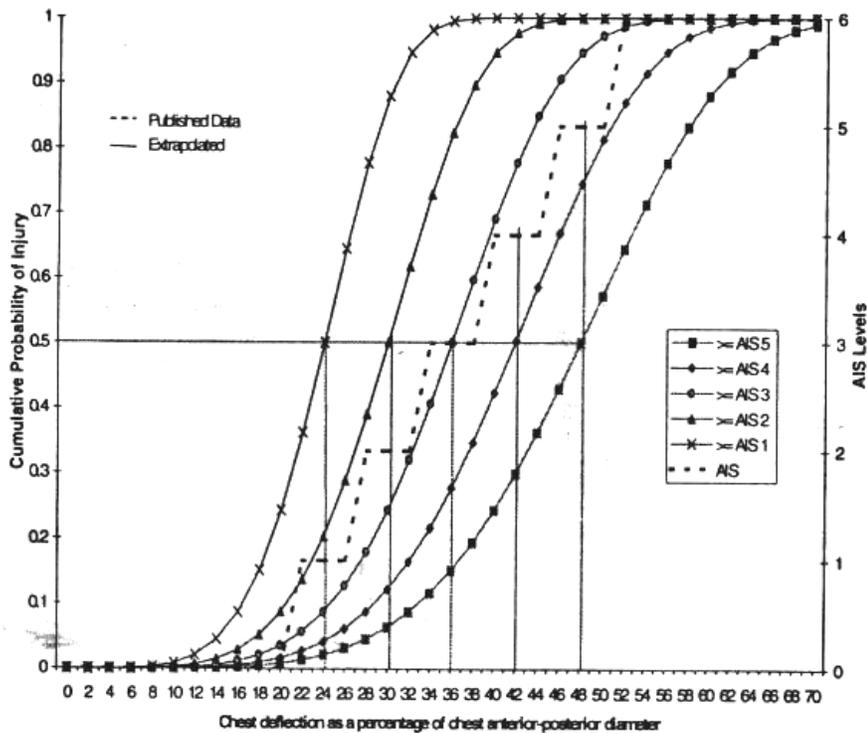


Figure 5. Graph of chest injury risk developed by Ryan (1998). The X-axis units are "percentage of chest diameter". For Hybrid III dummy the chest diameter is 223mm meaning a percentage value of 10 corresponds to a deflection of 22mm.