# How serious are they? The use of data linkage to explore different definitions of serious road crash injuries

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## Abstract

Over recent years, the focus in road safety has shifted towards a greater understanding of road crash serious injuries in addition to fatalities. Police reported crash data are often the primary source of crash information; however, the definition of serious injury within these data is not consistent across jurisdictions and may not be accurately operationalised. This study examined the linkage of police-reported road crash data with hospital data to explore the potential for linked data to enhance the quantification of serious injury. Data from the Queensland Road Crash Database (QRCD), the Queensland Hospital Admitted Patients Data Collection (QHAPDC), Emergency Department Information System (EDIS), and the Queensland Injury Surveillance Unit (QISU) for the year 2009 were linked. Nine different estimates of serious road crash injury were produced. Results showed that there was a large amount of variation in the estimates of the number and profile of serious road crash injuries depending on the definition or measure used. The results also showed that as the definition of serious injury becomes more precise the vulnerable road users become more prominent. These results have major implications in terms of how serious injuries are identified for reporting purposes. Depending on the definitions used, the calculation of cost and understanding of the impact of serious injuries would vary greatly. This study has shown how data linkage can be used to investigate issues of data quality. It has also demonstrated the potential improvements to the understanding of the road safety problem, particularly serious injury, by conducting data linkage.

## Introduction

In order to reduce the burden of road crash injuries, there is a need to fully understand the nature and contributing circumstances of crashes and the resulting injuries. The National Road Safety Strategy 2011-2020 (Australian Transport Council, 2011) outlines plans to reduce the burden of road trauma via improvements and interventions relating to safe roads, safe speeds, safe vehicles, and safe people. It also highlights that a key aspect in achieving these goals is the availability of comprehensive data on road crashes and related injuries. The use of data is essential so that more in-depth epidemiologic studies of risk profiles can be conducted as well as enable effective monitoring and evaluation of road safety interventions and programs.

Over the years there have been significant reductions in fatalities in Australia (The Parliament of Victoria Road Safety Committee, 2014), as there has been in many other highly motorised countries (International Traffic Safety Data and Analysis Group (IRTAD), 2011). However, there has been less of a reduction (and in some cases an increase) in the number of serious non-fatal road crash injuries in many of these jurisdictions, including Australia. This in combination with the substantial burden of serious non-fatal road crash injuries has meant that nationally and internationally, the focus in road safety has shifted towards a greater understanding of road crash serious injuries in addition to fatalities (International Traffic Safety Data and Analysis Group (IRTAD), 2011; The Parliament of Victoria Road Safety Committee, 2014). Police reported crash data are the primary source of crash information in most jurisdictions (International Traffic Safety Data and Analysis Group (IRTAD), 2011). Unfortunately, however, the definition of serious injury within police-reported data is not consistent across jurisdictions and may not be accurately operationalised, which could lead to misleading estimates of the impact and cost of crashes (D'Elia & Newstead, 2015).

The definition of a fatality is relatively consistent across countries since it is based on that of the Organisation for Economic Co-operation and Development (OECD) whereby a traffic death is one that occurs within 30 days of a road crash. In terms of other severity levels, particularly in relation to serious injury, the definitions are much more variable (D'Elia & Newstead, 2015). Many of the countries in the OECD define a serious injury as a person who is admitted to hospital for 24 hours or more as a result of a road crash (World Health Organization, 2010). However, this definition generally relies on the police identifying seriously injured persons based on whether they were transported to hospital or not. Given the reported lack of liaising between police and hospitals on whether admission actually occurred or on the length of admission, a serious injury category using this definition could range from cuts and bruises to severe head injuries (Ward et al., 2010). Another study by the authors (Watson, Watson, & Vallmuur, 2013), suggest that the 'hospitalisation' severity category used by police does not reflect true hospitalisations in all cases, at least within the state of Queensland. Further, it highlighted the wide variety of severity levels within hospitalised cases that are not captured by the current police-reported definitions.

As a result of this broad, and likely inconsistent, serious injury classification, more objective and precise measures of severity, based on threat to life, have been proposed (International Traffic Safety Data and Analysis Group (IRTAD), 2011) which rely on either police assigning a nature of injury code or on the use of hospital discharge diagnoses (e.g., Abbreviated Injury Scale, ICISS). The Abbreviated Injury Scale (AIS) is a body-region based coding system developed by the Association for the Advancement of Automotive Medicine (Association for the Advancement of Automotive Medicine, 2008). A single injury is classified on a scale from 1-6 (1 = minor; 2 = moderate; 3 = serious; 4 = severe; 5 = critical; and 6 = maximum). Another example of a more precise measure of severity is the International Classification of Diseases–based Injury Severity Score (ICISS) (Osler, Rutledge, Deis, & Bedrick, 1996). ICISS involves using ICD diagnoses to calculate threat-to-life associated with an injury. Survival Risk Ratios (SRR) are based on studies using large hospital datasets with death outcomes and the calculation of the survival probability (proportion of cases who do not die) for each ICD code (e.g., Stephenson, Langley, Henley, & Harrison, 2003). Cases are then assigned an ICISS, which is the multiplication of SRRs of all their diagnoses. It should be noted that there is some debate surrounding the most appropriate injury severity classifications, however these two measures are widely accepted and often used in injury research as reasonably reliable measures of the probability of death (Langley & Cryer, 2012; Stephenson, Langley, Henley, & Harrison, 2003). While it is acknowledged that hospital staff do not generally have training in the direct assignment of 'threat to life' measures, they are trained in assigning ICD diagnoses which can be mapped to AIS and/or SRRs using data obtained from trauma studies (e.g., Stephenson, Langley, Henley, & Harrison, 2003).

It could be suggested, however, that even if more detailed information was collected in order to assign these more objective and/or precise measures, the police are not necessarily in the best position to collect this information. Police do not have the training or expertise to record information on the nature of an injury, or injuries, with the required level of accuracy. Also, even if they were trained to assess this, classifying injury at the scene of a crash could be problematic, as not all injuries are apparent at the scene and the police have many competing priorities in these situations (e.g., traffic control). Also, it is argued that the consistency of the recorded information from case to case could be questionable if collected by the police (Amoros, Martin, Chiron, & Laumon, 2007; Chapman & Rosman, 2008; Farmer, 2003; McDonald, Davie, & Langley, 2009; Ward et al., 2010). The World Health Organisation (2010) suggests some possible strategies for addressing the issue of serious road crash injuries, including data linkage between police and hospital databases either routinely or periodically to check the accuracy of the police data; and/or the following up of cases by police (or reported by the hospital) to determine the length of the hospital stay.

This study aimed to examine the first of these strategies, namely the linkage of police-reported road crash data with a comprehensive linked hospital data set (including emergency department presentations and admitted patients' data). It specifically examines the potential for linked data to enhance the quantification of serious injury for those cases that link with police-reported data. It also explores issues such as under-reporting of road crash injuries to police and the different road user profiles of serious injury using different combinations of data and different definitions of serious injury.

**Methods**

Ethics approval was obtained from the Queensland Health Human Research Ethics Committee (#HREC/12/QHC/45).

*Data collections*

Data were provided from the Queensland Road Crash Database (QRCD), Queensland Hospital Admitted Patients Data Collection (QHAPDC), Emergency Department Information System (EDIS), and Queensland Injury Surveillance Unit (QISU) by each relevant custodian for the specified cases for 2009. The year 2009 was used as it was the most recently available data for all collections at the time the linkage was commenced. There are often significant delays with data being available to researchers. Also, gaining the necessary custodian approvals and the data linkage (conducted by the Queensland Health Record Linkage Group) took twenty months to complete. The QRCD includes all road crash injuries reported to police in Queensland in 2009. This includes information about all persons injured on public roads, including drivers, passengers, motorcycle riders, cyclists, and pedestrians. It should be noted that the following major exclusions apply:

- The incident occurs in an area outside the road or road related area.

- There is no moving vehicle involved.

- The incident is not attributable to vehicle movement.

It should be noted that the definition of what constitutes a road crash injury in this study is based on this QRCD definition

QHAPDC contains data on all patients discharged, statistically separated, died, or transferred from a Queensland hospital permitted to admit patients (including public hospitals, licensed private hospitals, and day surgery units). External cause of injury information is captured in three data fields (i.e., external cause, place, and activity) using International Classification of Diseases 10th Edition, Australian Modification (ICD-10-AM) (National Centre for Classification in Health, 2004).

The Emergency Department Information System (EDIS) includes all emergency department presentations in twenty-nine hospitals across Queensland (approximately 75% of Queensland emergency departments). This collection does not code cause of injury information and requires the use of the 'presenting problem' text description to identify transport-related cases. However, the principal diagnosis is coded using ICD-10-AM.

The Queensland Injury Surveillance Unit collects data on injuries presenting at seventeen Queensland emergency departments (nine of the QISU hospital emergency departments are not included in EDIS). This collection captures cause of injury information in several data fields both coded and text-based, including: mechanism, external cause, major injury factor, place, activity, and an 'injury description' text field.

The following was determined as the selection criteria for each collection were used to capture of the population of interest:

- QRCD: all police-reported injury cases
- QHAPDC: all admitted patients cases coded as transport-related (ICD-10-AM External Cause Codes from V00-V99)
- EDIS: all emergency department cases coded as an injury (discharge diagnosis S00-S99 and T00-T98)
- QISU: all emergency department injury cases coded as transport-related (external definition of 'motor vehicle – driver'; 'motor vehicle – passenger'; 'motorcycle – driver'; 'motorcycle – passenger'; 'pedal cyclist or pedal cyclist passenger'; and 'pedestrian')

It should be noted that for the data linkage component (conducted by the Queensland Health Record Linkage Group), all injury cases in EDIS and all transport injury cases in QISU and QHAPDC were processed for linkage. This was done as there was some question over the accuracy of the coding of traffic (road-related) injuries in QHAPDC and QISU and the selection of transport injuries in EDIS (as this data collection only contains cause of injury information in an unstructured text field as described above). So, in order to capture those cases that may still link to the QRCD (police-reported data) despite not being coded or identified as a road crash in the three hospital data sets, a broader approach to the linkage was used. The researchers then applied the refinements described in the next section to identify relevant road crash cases for analysis.

### Data linkage process

Person details and demographic data were linked using deterministic & probabilistic methodologies, as well as manual clerical reviews where required. QRCD was merged with the other data collections. The data sets were merged based on the person ID. If the person ID of a QRCD case matched the person ID of any case in the other data sets, then the case was considered to be a link and was coded as such. Non-links were all cases in QRCD that did not have a person ID in common with any case in the other data collections. Non-links, for the purposes of calculating under-reporting, were all cases in the other data collection that did not have a person ID in common with QRCD. The hospital (i.e., presented at hospital) data collections (i.e., QHAPDC, EDIS, and QISU) were combined to form a *hospital population* data set. This data set included all cases from each collection that linked to each other as well as the unique (non-linked) cases from each data collection. This combined data set was then used as the basis for the population estimates for comparison to QRCD.

### Selection of cases and coding of variables

The selection of road crashes for each data collection was as follows:

- QRCD – all casualties
- QHAPDC – All acute admissions with ICD-10-AM External Cause Codes from V00-V89 and fourth character of 'traffic'
- QISU – All cases with an *External definition* (Motor vehicle – driver; Motor vehicle – passenger; Motorcycle – driver; Motorcycle – passenger; Pedal cyclist or pedal cyclist passenger; Pedestrian) and *type of place* (street/highway)
- EDIS – All cases with a *Presenting problem* keyword search relating to crashes (e.g., car, motorbike, pedestrian) without exclusion terms (e.g., off-road, track)

The Abbreviated Injury Scale (AIS) was coded as (1 = minor; 2 = moderate; 3 = serious; 4 = severe; 5 = critical; and 6 = maximum). The Survival Risk Ratio (SRR) is an estimate of the probability of

death from 0 (no chance of survival) to 1 (100% chance of survival). These two severity indicators were coded for QHAPDC, QISU, and EDIS using the *Principal diagnosis* ICD-10-AM codes mapped to the AIS and a SRR. SRR was mapped to ICD-10-AM using the values assigned from Stephenson and colleagues (2003). A tool for mapping ICD-10 codes to AIS score was sourced from the European Center for Injury Prevention. While this mapping is for ICD-10 to AIS, not ICD-10-AM, the principal diagnosis coding is compatible between the systems at a lower level of specificity (4th character).

Road user was coded as 1 = Driver, 2 = Motorcyclist, 3 = Cyclist, 4 = Pedestrian; 5 = Car passenger. The following variables were used for each of the data collections:

- QRCD – *casualty road user type*
- QHAPDC – second and fourth characters of the ICD-10-AM *external cause code*.
- QISU – *external code* (motor vehicle – driver = driver; motorcycle – driver and motorcycle – passenger = motorcyclist; pedal cyclist or pedal cyclist passenger = cyclist; pedestrian = pedestrian; motor vehicle passenger = passenger)
- EDIS – *Presenting problem* text search (e.g., driver = driver; motorcycle, MCA, MBA = motorcyclist; bicycle, PBS, PBA = cyclist; passenger = passenger; none of the keywords = unspecified)

In cases where more than one health data collection was combined with QRCD, there was a hierarchy for selection of which data collection would provide the data in the variables. For example, if the case has a specified ICD-10-AM principal diagnosis code in QHAPDC, this was the code that was used. The ICD-10-AM coding in QISU was used when QHAPDC was not available and the ICD-10-AM code for EDIS was used in cases where neither QHAPDC nor QISU code is available. This hierarchy was based on the assumption that QHAPDC coding of injury is superior to QISU and EDIS, as it is completed by trained coders with access to the full medical records of the patients. QISU would be considered next best, as it has coded information for most variables, and EDIS last, as many of the variables rely on being created from text searching.

### *Serious injury definitions*

Using the different combinations of linked and non-linked data, the following estimates of the number of serious injuries were produced:

1. Police reported 'hospitalisations' (QRCD)

2. Hospital attendances (EDIS, QHAPDC, QISU)

3. Hospital admissions of 24hrs or more (QHAPDC)

4. Confirmed hospital attendances reported to police (QRCD linked with hospital)

5. Confirmed hospital admissions of 24hrs or more reported to police (QRCD linked with QHAPDC)

6. Confirmed serious injuries as defined by AIS > 3 reported to police (QRCD linked with hospital)

7. Confirmed serious injuries as defined by SRR < .942 reported to police (QRCD linked with hospital)

8. Hospital serious injuries as defined by AIS > 3 (QHAPDC, EDIS, QISU)

9. Hospital serious injuries as defined by SRR < .942 (QHAPDC, EDIS, QISU)

It should be noted that 'hospitalisations' in QRCD are defined as 'taken to hospital'.

The road user profile was compared for each of the serious injury definitions and population combinations outlined above.

**Results**

As shown in Table 1, the number of serious road crash injuries identified as occurring in Queensland in 2009 differs depending on both the population source and the definition of a serious injury. Based on the current practice in Queensland (police-reported 'hospitalised' - taken to hospital), approximately 6,500 cases would be defined as serious. If the number of police-reported road crash injuries that were actually 'taken to hospital' is considered (based on the cases linked with the hospital data set), the number of serious injuries rises to approximately 10,000. Using police-reported cases as the population, the highest number of serious injuries would be obtained by including all cases that are reported to police (i.e., are included in the QRCD) and attend hospital (i.e., link with the hospital data set). The lowest numbers of serious cases are identified from police reported cases that have an AIS higher than 3. When examining serious injury for cases identified in the *hospital data set* (not necessarily reported to police), attending hospital definition of serious yields the highest number of serious injuries. If the international definition of a serious injury ('hospitalised' for 24 hours or more) is applied, almost 30% of *police reported and defined as 'hospitalised'* fit this definition. This number doubles if the entire *hospital data set* is used (regardless of whether the case is reported to police). It should also be noted that as the definition of a serious injury becomes more specific (i.e., AIS and SRR), the discordance between police reported and the *hospital data* cases (under-reporting) narrows. However, even for the AIS and SRR defined serious *hospital data* cases, between 30% and 40% were not linked to police data.

*Table 1: Number of police reported and hospital serious injuries based on different definitions*

| Definition | Police reported | Hospital cases | % Discordance |
|---|---|---|---|
| Police definition 'hospitalised' | 6,674 | - | |
| Attended hospital | 10,649 | 29,261 | 63.6 |
| Admitted hospital > 24hrs | 1,879 | 3,474 | 45.9 |
| AIS > 2 | 672 | 1,110 | 39.5 |
| SRR < .942 | 1,041 | 1,507 | 30.9 |

As shown in Table 2, the road user profile for *police-reported and defined as 'hospitalised'* (i.e., police-reported taken to hospital) and the *police-reported attending hospital* were very similar. Within the police-reported serious injuries, the road user profile was different for the more specific definitions of serious injury (e.g., SRR and AIS), with a greater proportion of motorcyclists, cyclists, and pedestrians. It should be noted however that the majority of police-reported serious injuries were drivers and passengers regardless of the serious injury definition applied. In contrast, when all cases were considered regardless of whether the injury was reported to police (i.e., hospital data cases), motorcyclists and cyclists together formed the majority of cases. Within the hospital data cases, there was some variation based on the definition of serious injury utilised. Specifically, based on the *admitted to hospital for 24 hours or more* serious injury definition, there was a higher proportion of motorcyclists, while there was a higher proportion of cyclists if the *attending hospital* definition is used.

*Table 2: Profiles of road crash serious injuries by road user type for Queensland in 2009*

| Variable | Level | Police 'hospitalised' % | Confirmed Attended % | Confirmed Admitted > 24hrs % | Confirmed AIS > 2 % | Confirmed SRR < .942 % |
|---|---|---|---|---|---|---|
| | | **Police-reported** | | | | |
| Road user | Driver | 53.6 | 55.1 | 39.9 | 39.6 | 44.9 |
| | Motorcyclist | 14.3 | 12.6 | 24.7 | 21.1 | 17.8 |
| | Cyclist | 5.3 | 4.8 | 6.4 | 6.5 | 6.2 |
| | Pedestrian | 6.4 | 5.6 | 10.9 | 12.4 | 11.0 |
| | Passenger | 20.5 | 21.9 | 18.1 | 20.4 | 20.2 |
| | | **Hospital data cases** | | | | |
| | | Police 'hospitalised' % | Attended % | Admitted > 24hrs % | AIS > 2 % | SRR < .942 % |
| Road user | Driver | - | 23.3 | 25.0 | 25.7 | 30.1 |
| | Motorcyclist | - | 29.7 | 38.4 | 33.9 | 26.9 |
| | Cyclist | - | 29.2 | 14.4 | 16.1 | 18.0 |
| | Pedestrian | - | 3.4 | 8.5 | 9.9 | 9.3 |
| | Passenger | - | 14.5 | 13.7 | 14.4 | 15.6 |

## Discussion

This analysis of the various Queensland road crash and hospital data collections has shown that there was a large amount of variation in the estimates of serious road crash injuries depending on the population of reference and the definition or measure used. If the current reporting practice definition within the police data is used (i.e., police-reported 'hospitalised'), there were around 6,000 serious road crash injuries in 2009. If the number of police-reported road crash injuries that were actually 'taken to hospital' is considered (based on the cases linked with the hospital data), the number of serious injuries rises to approximately 10,000. If the international definition of a serious road crash injury is applied (i.e., admitted to hospital for 24 hours or more), there was slightly less than 2,000 serious road crash injuries reported to police. When AIS and SRR are used to classify serious injury the numbers are approximately 600 (AIS > 3) and 1,000 (SRR < .942) serious injuries respectively, reported to police. The number of serious injuries increases dramatically, if all injury cases are considered, not just those reported to police. Specifically, if all cases 'taken to hospital' (regardless of whether they are reported to police) are counted, there were almost 30,000 serious injuries. In contrast, if the admitted to hospital for 24 hours or more definition is used then there were around 3,500 cases, while AIS and SRR based definitions provided estimates of approximately 1,000 and 1,500 cases respectively.

It should also be noted that as the definition of serious becomes more specific (i.e., AIS and SRR), the discordance between police reported and the *hospital data* cases (under-reporting) narrows. However, there is still some discordance even for these more specific measures, indicating that some potentially very serious cases are not reported to police.

The road user profile for *police-reported and defined as 'hospitalised'* and the *police-reported attending hospital* were very similar. Within the police-reported serious injuries, the road user profile was different for the more specific definitions of serious injury (e.g., SRR and AIS), with a greater proportion of motorcyclists, cyclists, and pedestrians being included. This result shows that as the definition of serious injury becomes more precise (and potentially represents the 'most' serious cases) the vulnerable road users become more prominent. However, regardless of the definitions utilised the majority of police-reported serious injuries were drivers and passengers. In contrast, when all cases were considered, regardless of whether the injury was reported to police (i.e., hospital data cases), motorcyclists and cyclists together formed the majority of cases. This

difference between police-reported and all hospital road crash injury cases likely reflects the under-reporting bias in police data. It has been shown in other studies that injuries involving these two road user groups are less likely to be reported to police (Alsop & Langley, 2001; Amoros, Martin, & Laumon, 2006; Boufous, Finch, Hayen, & Williamson, 2008; Langley, Dow, Stephenson, & Kypri, 2003; Watson, Watson, & Vallmuur, 2015). It is acknowledged however, that while only those coded as 'traffic' and/or without exclusion terms such as 'off-road' 'track' and 'trail' were included in the hospital data collections for comparison (i.e., most likely to compare to the definitions of on-road in the police data), this classification may not always be accurate. As a result, the under-reporting found in this study (and in others) may be over-estimated.

These results have major implications in terms of how serious injuries are identified for reporting purposes. Depending on the definitions and population used, the calculation of cost and understanding of the impact of serious injuries would vary greatly. It has been recommended previously that hospital data could be used to link with police data to gain a greater understanding of the serious injury problem. However, there has been little previous work conducted on understanding the inclusion criteria and definitions. This understanding is clearly required given the large discrepancies in the numbers and patterns of serious injuries arising from different definitions.

An important issue that should be noted relates to the mapping of ICD-10-AM coding to AIS and SRR. For SRR, the mapping corresponds directly to ICD-10-AM. However, the AIS mapping corresponds to ICD-10 and is then extrapolated to ICD-10-AM. The correspondence between ICD-10 and ICD-10-AM is at a level less specific, making mapping less precise. As a result the reliability of the assignment of AIS may be in question. In addition, for both AIS and SRR, there were still a number of cases in the *hospital data* that could not be assigned a value, while this was not a large proportion it may still be considered significant. Further research should be conducted to improve the current severity mapping practices. Also, status of ICD-11 should be monitored as this new coding system may better allow for mapping to these measures. A related limitation is the use of a single SRR rather than using multiple SRRs to form an International Classification of Diseases Based Injury Severity Score (ICISS). It was not possible to compute ICISS in this study as only one diagnosis was available in the EDIS and QISU data collections. While there has been some research suggesting that a single SRR may be just as useful as the multiplicative method (Henley & Harrison, 2009), this assumes the single diagnosis is the 'worst injury' that an injured person has sustained. It could be argued that the principal diagnosis could represent the 'worst injury'; further examination of this issue with the current data may be the subject of future research. The other limitation relating to severity coding, concerns the use of 'threat to life' measures. Further research could examine the potential of other injury severity indicators (e.g., Disability Adjusted Life Years (DALYs), length of stay), to explore the impact of injuries not just in terms of 'threat to life', but also the impacts of disability and the burden on the health system.

While this program of research was conducted using Queensland data, the results do have international implications. The World Health Organisation (2010 has suggested conducting linkage studies periodically to assess police classification of injury severity against measures such as the Abbreviated Injury Scale (AIS). WHO (2010) also suggests applying a standard methodology to assess under-reporting of serious injuries in police data and apply conversion factors to police road crash injury data to provide a more accurate estimate.

It is possible that such a linkage could be restricted to police data and those collections that have the most relevance and/or are the most accurate (e.g., only QHAPDC for hospitalised injuries). Specifically, linkage with QHAPDC could be conducted more routinely to confirm the hospitalisation status of a police-reported road crash injury; this would be a good first step to improving serious injury reporting and would be consistent with current recommendations in Australia (The Parliament of Victoria Road Safety Committee, 2014). Ultimately, data linkage

could potentially improve the reporting practices and epidemiological study in road safety. While it is unlikely that non-fatal injury data will ever be as accurate and reliable as fatal data; data linkage could be used to make substantial improvements.

This study has shown how data linkage can be used to investigate issues of data quality particularly in relation to defining serious injury. It has also demonstrated the potential improvements to the understanding of the road safety problem, particularly serious injury, by conducting data linkage. Even if linkage was not performed routinely, further research could be conducted to develop adjustments based on linked data, which could then be applied routinely to current reporting, for a more accurate representation of the serious road crash injury problem.

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