Prehospital, Resuscitation and Emergency Care Research Unit
Curtin School of Nursing

Conscious State Assessment in Emergency Ambulance Calls in Western Australia

Jason Laurence Belcher

0000-0002-3316-9043

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Declaration

To the best of my knowledge and belief this thesis contains no material previously published by any other person except where due acknowledgment has been made.

This thesis contains no material which has been accepted for the award of any other degree or diploma in any university.

Human Ethics: The research presented and reported in this thesis was conducted in accordance with the National Health and Medical Research Council National Statement on Ethical Conduct in Human Research (2007) – updated March 2014. The proposed research study received human research ethics approval from the Curtin University Human Research Ethics Committee (EC00262), Approval Number HR128/2013-46.

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Abstract

Background: In an emergency ambulance call, one of the key responsibilities of the Emergency Medical Dispatcher (EMD) is to triage patient acuity. Ambulance services necessarily triage incoming calls to ensure that appropriate resources are allocated, and calls appropriately prioritised, so that patients with life threatening conditions do not wait for less acute presentations.

Internationally-used triage systems for emergency ambulance calls such as the Medical Priority Dispatch System (MPDS) use the patient's conscious state as a major criterion for prioritising calls. However, the value of this approach depends on the accuracy with which patient conscious state can be determined.

For this thesis, I researched the accuracy of conscious state assessment during telephone triage, using data from the Western Australian ambulance service, St John Western Australia (SJWA), who use the MPDS to process emergency calls. After EMDs provide the prompt "Tell me exactly what happened.", they ask about consciousness per se ("Is [the patient] awake?"), followed by "Is [the patient] breathing?" They then choose one of 32 protocols that best represents the broad nature of the complaint. Importantly, in most protocols there is an initial follow-up question "Is [the patient] completely alert?", with an answer of "no" indicating an altered conscious state. I sought to analyse the accuracy of this assessment of altered conscious state, and surrounding factors.

Aims: The research project aimed to:

1. Review the current literature on the accuracy of conscious state assessment in emergency calls;
2. Analyse the accuracy of conscious state assessment in emergency ambulance calls compared to scene findings by paramedics in Western Australia;
3. Determine the relationship between ambulance patients' initial presenting conscious state (as determined on scene by paramedics) and patient acuity; and to determine how the strength of this relationship differs between MPDS protocols.

Methods and Results:

Systematic Review

A systematic review was conducted into the accuracy of call-taker assessment of conscious state in emergency calls. This was based on the concepts of prehospital care or emergency medical services; conscious state; triage, telecommunication, or dispatch; and accuracy or reliability. Papers were included if they dealt with calls for help to emergency medical services in the community, reported the call-taker's determination of the patient's level of consciousness, and directly compared this to the level of consciousness as determined on arrival of responders.

While a total of 5,753 papers were identified through the initial search, only two papers met the final inclusion criteria. Both papers reported the accuracy of determination of consciousness versus unconsciousness in the initial telephone call compared to findings on scene, and found that it is common for reported consciousness to differ to what is found on responder arrival. No studies were identified measuring accuracy of determination of altered conscious states amongst conscious patients.

Cohort Study 1: Accuracy of call-taker determination of conscious state

A retrospective diagnostic accuracy study was performed on one year of data for emergency ambulance responses in Perth. The study compared each patient's Alert/Not Alert status as recorded by the EMD using MPDS, to the patient's initial presenting conscious state on arrival of paramedics. Measures of diagnostic accuracy (sensitivity, specificity, positive and negative predictive values) were produced across the whole dataset, and stratified by MPDS protocols.

A total of 109,968 calls were included for analysis. Of these, there were 1,282 true positives (Not Alert at dispatch and on paramedic assessment), 89,768 true negatives (Alert at dispatch and on paramedic assessment), 551 false negatives (Alert on dispatch, Not Alert on paramedic assessment) and 18,077 false positives (Not Alert on dispatch, Alert on paramedic assessment). There were more than 10 times as many calls (19,359 versus 1833) dispatched as Not Alert compared to patients found to be Not Alert. The positive predictive value was 6.6%, and sensitivity was 69.9%.

Cohort Study 2: Association between patient conscious state and acuity

Using the same cohort as Cohort Study 1, I measured the association between each patient's presenting conscious state on arrival of paramedics, and their acuity. Conscious state was measured on a six-level descriptive scale (Alert, Confused, Drowsy, Voice response, Pain response, Unresponsive), and acuity based on a high acuity filter developed internally by SJWA (based on the presence of defined codes for paramedic assessment, observations, or interventions). Measures of diagnostic accuracy for predicting high acuity patients were calculated using each individual level of consciousness as a threshold predictor, with a view to identifying thresholds to use in telephone triage. The Area Under the Curve (AUC) of the Receiver Operating Characteristic (ROC) curve was calculated for each MPDS protocol, to identify protocols with the strongest association between presenting conscious state and acuity.

Across the whole dataset, 22% of patients were classified as high acuity. Comparing patient acuity across the six levels of patient consciousness, the proportion of high acuity patients increased with each increment in patient consciousness. When treating each level as a threshold level (i.e., including patients with the selected level of consciousness *and below – i.e. less conscious*), the rate of high acuity patients was 48.6% for Confused, 61.9% for Drowsy, 89.5% for Voice Response, 93.6% for Pain response, and 98.6% for Unresponsive. The AUC of the ROC for the whole dataset was 0.65. Within individual protocols, the highest AUC was in Cardiac Arrest (0.89), Overdose/Poisoning (0.81), Unknown Problem (0.76), Diabetic Problem, (0.74) and Convulsions/Fitting (0.73); and lowest in Heart problems (0.55), Abdominal Pain (0.55), Breathing Problems (0.55), Back Pain (0.53), and Chest Pain (0.52).

Conclusions:

My systematic review identified a significant knowledge gap in the literature on the accuracy of assessment of conscious states in emergency calls, which my thesis addressed.

In the context of Emergency Medical Services taking a risk-averse approach to ambulance dispatch, my expectation was to see evidence of over-triage, in terms of a greater tendency for patients being classified as not alert relative to their condition on scene. Consistent with this expectation was my finding of a very low positive predictive value for patients being not alert.

However, surprisingly, I also found a modest sensitivity, whereby many patients found not alert on scene were dispatched as alert. This indicates that the inaccuracies of determining patients as not alert versus alert are not simply a case of over-triage, but apply in both directions in terms of high numbers of both false positives (dispatched as not alert, but alert on scene) and false negatives (dispatch as alert, but not alert on scene). Further investigation is needed into how to optimally question callers in a rapid triage sequence, in a way that is understood by callers and produces a reliable answer.

At a system-wide level, there appears to be no clear threshold level of consciousness that accurately discriminates high-acuity patients from lower acuity patients. However, even among patients with the smallest decrease in reported consciousness beyond being alert (i.e. when classified as confused or worse) 49% of patients were high acuity. On this basis, it would be reasonable to treat any patient with an altered conscious state as a high priority from an ambulance triage perspective. This is in keeping with the wording of the question in MPDS. Patient conscious state was strongly predictive of acuity for patients on the Overdose/Poisoning, Diabetic Problem and Convulsion/fitting MPDS protocols; and secondary triage services may add value in these patient groups by further questioning conscious states to ensure appropriate resource and priority allocation.

Publications and Presentations

The following publications were produced as a part of the research contained in this thesis:

1. **Belcher J**, Finn J, Whiteside A, Ball SJ. Accuracy of call-taker assessment of patient level of consciousness: a systematic review. *Australasian Journal of Paramedicine*. 2020;17:1-9. doi:10.33151/ajp.17.741
2. **Belcher J**, Finn J, Whiteside A, Ball S. 'Is the patient completely alert?' – accuracy of emergency medical dispatcher determination of patient conscious state. *Australasian Journal of Paramedicine*. 2021;18:1-10. doi:10.33151/ajp.18.858
3. **Belcher J**, Finn J, Whiteside A, Ball S. Association between initial presenting level of consciousness and patient acuity – A potential application for secondary triage in emergency ambulance calls. *Australasian Emergency Care*. 2023;26(3):199-204. doi:10.1016/j.auec.2022.11.002

A summary of the research was presented at the Australasian College of Paramedicine International Conference in 2022:

Belcher J, Finn J, Whiteside A, Ball S. Conscious state assessment in emergency ambulance calls in Western Australia. Presented at: Australasian College of Paramedicine International Conference; 15 September 2022; Brisbane, Australia.

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List of Abbreviations

The following abbreviations are used throughout this thesis:

ACDU	Alert, Confused, Drowsy, Unresponsive
ALS	Advanced Life Support
AUC	Area Under the Curve
AVPU	Alert, Voice response, Pain response, Unresponsive
BLS	Basic Life Support
CAD	Computer Aided Dispatch
CBD	Criteria Based Dispatch
EMD	Emergency Medical Dispatcher
EMS	Emergency Medical Service
ePCR	Electronic Patient Care Record
EWS	Early Warning Score
FN	False Negative
FP	False Positive
GCS	Glasgow Coma Scale
HAM	History, Assessment or Management (ePCR code)
MPDS	Medical Priority Dispatch System
NPV	Negative Predictive Value
OHCA	Out of Hospital Cardiac Arrest
PPV	Positive Predictive Value
PRECRU	Prehospital, Resuscitation and Emergency Care Research Unit
PRISMA	Preferred Reporting Items for Systematic Reviews and Meta-Analysis
ROC	Receiver Operating Characteristic
SJWA	St John Western Australia
SOC	State Operations Centre
TN	True Negative
TP	True Positive
WA	Western Australia

Chapter 1. Introduction

Ambulance or Emergency Medical Services (EMS) typically receive a call for help for a patient in the community via an emergency number such as 000, 999, 911, 111, and 112. Ambulance call-takers taking these calls need to use a triage process to determine the appropriate ambulance or EMS response required. Sending appropriate ambulance responses to calls for help requires determining patients' acuity and their likely needs at the point of the emergency call.

Different responses can involve the priority of calls (which calls are prioritised for attendance), response mode (lights-and-sirens versus normal road conditions), capability of responders (Basic Life Support versus Advanced Life Support), and additional resources (such as a single responder backup or specialised resources). For lower acuity calls, alternative responses such as telephone referral or single paramedics in an extended care paramedic pathway can be used.

There is inherent risk in any triage process, and ambulance services worldwide have reported inaccuracies in triage[1-8]. Under-triage (where a patient is given a lower priority or sent a lower capability than required) is a clinical risk to that individual patient. Over-triage (where a patient is given a higher priority or sent a higher capability than required) creates a systemic risk where resources are exhausted, so the truly high acuity patient has a longer wait for care[8-11].

Ambulance services may use different methods to triage incoming emergency calls. These include employing clinically-trained staff taking all calls and using their own knowledge to assign a triage priority, or use of a variety of decision support systems that can be used by clinicians and trained lay people. One of the most commonly used decision support systems in Australia along with the United States and United Kingdom is the Medical Priority Dispatch System (MPDS)[12]. A second, Criteria Based Dispatch (CBD)[13], is commonly used in Europe and the United States.

A key area of questioning in triage is around patient conscious state. Complete loss of consciousness can indicate a highly acute medical condition or traumatic injury. In conscious patients, an altered conscious state can be symptomatic of serious conditions such as stroke[14], head trauma[15], hypoglycaemia[16] or poisoning[17]. Questions around conscious state appear in prehospital phone triage systems such as MPDS and CBD, and conscious state assessment also features in face-to-face emergency triage systems such as the Australasian Triage Scale[18], Manchester Triage System[19] and Canadian Triage Assessment Scale[20].

In the setting of an emergency ambulance call, the value of conscious state assessment as a triage criterion relies on how accurately a patient's level of consciousness can be determined during calls. Inaccuracies have potentially significant implications for ambulance services in terms of both under- and over-triage. An increased understanding of accuracy of determining conscious state during dispatch may lead to improvements which will overall increase triage accuracy and, in turn, more appropriate resource utilisation in prioritising the correct patients.

1.1. Research Rationale

Determining "true non-alertness" has been identified as one of the "holy grails" – a key goal of ongoing research into emergency medical dispatching – by the original creator of MPDS[21]. A system that does not reliably determine true non-alertness may frequently inaccurately triage patients as having an altered conscious state. This in turn may cause a large amount of over-triage for the patients classified as "not alert". As detailed above, such over-triage may lead to significant risk to communities by making ambulance services unavailable when a truly high acuity patient presents due to the diminished reserves of resourcing.

This view of over-triage has been articulated by the ambulance service in Western Australia[22]; and a potential solution proposed of downgrading priority responses to patients identified with an altered conscious state. However, analysis of these cases showed that this would lead to a high level of high acuity patients being under-triaged, and this proposal was recommended against[22].

This research therefore was born out of a desire to understand accuracy or otherwise of conscious state determination in an emergency dispatch setting. Furthermore, I hope to make recommendations around improving assessment of patient conscious states in this context, and thus contribute to the goal of improving triage more broadly and attempting to facilitate the right care for the right patient at the right time.

1.2. Research Aims and Objectives

The overall aim of this thesis is to understand the accuracy and utility of conscious state assessment during triage of ambulance calls in the Western Australian ambulance service context.

To achieve this aim, I conducted research with the following objectives:

1. To understand the current literature surrounding accuracy of conscious state assessment in the setting of ambulance calls, by means of a systematic review.
2. To measure the accuracy of call-taker assessment of conscious state in the Western Australian ambulance service by comparing the reported conscious state in the emergency call to the conscious state recorded on arrival of paramedics.
3. To measure the association between the patient's presenting conscious state (as assessed by the paramedics on arrival at the scene) and the patient's acuity. To use this information to identify types of calls (presenting complaints) that may most benefit from a more thorough assessment of conscious state, and thereby inform emergency telephone triage.

1.3. Thesis Approach

This thesis is based on a compilation of peer reviewed publications and supporting chapters. An overview of each chapter is provided in the following table (Table 1):

Table 1: Thesis overview

Chapter	Contents	Research Aims
Chapter 1	Introduction	Describe the background and rationale of the thesis Describe the aim of the thesis and research objectives Provide an overview of the structure of the thesis
Chapter 2	Background	Provide background information about the context of the research (Perth, Western Australia, and its ambulance service) Provide background information about the telephone triage system used in Western Australia (Medical Priority Dispatch System, MPDS) Provide background information on key measures of conscious states in emergency health care
Chapter 3	Concept and Methodology	Provide an overview of the study methods, including data sources, definitions and analysis.

Chapter 4	Systematic Review (Research objective 1)	
	Manuscript: *Accuracy of call-taker assessment of patient level of consciousness: a systematic review*	To summarise the current literature on the accuracy of conscious state assessment in the setting of ambulance calls, by means of a systematic review.
Chapter 5	Analysis of accuracy (Research objective 2)	
	Manuscript: *'Is the patient completely alert?' – accuracy of emergency medical dispatcher determination of patient conscious state* Also includes supporting further analysis with sensitivity analysis based on alternative threshold of conscious state	To measure the accuracy of conscious state assessment by call-takers in the Western Australian ambulance service by comparing the reported conscious state in the emergency call to the conscious state recorded on arrival of paramedics.
Chapter 6	Analysis of conscious state versus acuity (Research objective 3)	
	Manuscript: *Association between initial presenting level of consciousness and patient acuity – a potential application for secondary triage in emergency ambulance calls*	To measure the association between a patient's presenting conscious state and their acuity. To measure the utility of conscious state as a predictor of acuity between different patient presenting conditions.

Chapter 7	Discussion	Summarise key findings Detail strengths and limitations of the research Detail recommendations arising and how they can be translated into practice

Chapter 2. Background

2.1. Introduction

The purpose of this chapter is to provide background information relating to measurement of patient conscious states, the Medical Priority Dispatch System, and the setting in which the research was conducted (St John Western Australia).

2.2. Study Period

My study was undertaken based on data from the period of 27 November 2017 – 26 November 2018. Unless stated otherwise, all background information in this chapter relates to the situation during that time period.

2.3. Setting – St John Western Australia

2.3.1. Ambulance Service overview

St John Western Australia (SJWA) operates the emergency ambulance service for the state of Western Australia (WA). Unlike most states in Australia where the jurisdictional ambulance service is a state government agency, SJWA is a private organisation, contracted by the state government[(23)].

Western Australia has an area of 2.53 million km^2 [(24)] and an estimated population of 2.60 million in 2018[(25)]. Based on this land mass, SJWA covers the largest area of any jurisdictional ambulance service in the world[(26)].

The Perth metropolitan area in the south-west of Western Australia had an estimated population of 2.06 million (79% of the population) for the same time period[(25)]. The remainder of the state is referred to as regional Western Australia.

There are 15 regional locations with career paramedic crewing, in major population centres, with the remainder of the state covered by a volunteer ambulance service[(27)].

2.3.1.1. Metropolitan Ambulance Service – Perth, Western Australia

This research focuses on the Perth metropolitan area. The uniqueness of Western Australia's geographic spread, sparseness, and associated challenges with timely responses would make any findings difficult to generalise to other areas.

As of 30 June 2018, SJWA's metropolitan ambulance service employed 903 paramedics and ambulance officers, working at 29 stations across the Perth metropolitan area[28]. Ambulance response in the metropolitan area is by career paramedic crews only, with at least one registered paramedic on each crew, with the other crew member being either another registered paramedic, or an ambulance officer in training to become a paramedic.

2.3.1.2. Staffing

During the study period, SJWA ambulance responses in the Perth metropolitan area were staffed by different levels of clinical staff:

Ambulance Paramedics:	Registered paramedics qualified in advanced life support under the SJWA Clinical Practice Guidelines, typically staff a transport-capable ambulance response.
Ambulance Officers:	Staff on a training pathway to qualify as paramedics, have completed or are completing an approved tertiary paramedic qualification. May be a registered paramedic depending on stage of qualification. Work with a qualified paramedic on an ambulance.
Clinical Support Paramedics:	Ambulance Paramedics who provide clinical leadership and support and occasionally additional clinical skills or medications to high acuity patients. May be first responder to some emergency calls. Typically in a non-transport single responder vehicle.
Area Managers:	Ambulance Paramedics who provide operational leadership, and scene management at more complex

incidents along with ability to clinically response. May first respond to some emergency calls. Operate in a non-transport single responder vehicle.

Critical Care Paramedics: Staff the Emergency Rescue Helicopter Service, are registered paramedics qualified in advanced life support and with additional skills and medications for managing major trauma or high acuity medical transfers. Practice at Ambulance Paramedic scope when not working on a rescue helicopter.

Ambulance Transport Officers: Officers trained to a basic life support scope, providing low acuity booked inter-facility transfers.

While ambulance crews in the Perth metropolitan area consist of two Ambulance Paramedics or an Ambulance Paramedic and an Ambulance Officer, additional resources such as Clinical Support Paramedics or Area Managers may also attend to an incident in addition to ambulance crews if specialist or experienced clinical care, or scene leadership, is required.

2.3.2. Response Priorities

There are three priority levels associated with emergency ambulance response in Western Australia[29], with target response times set in the contractual agreement under which SJWA operates. The system is designed such that the presentation of a higher priority call can cause a crew responding to a lower priority to be diverted to the new call if they are the closest resource.

- **Priority 1**: Considered *Emergency* calls. These have an immediate dispatch to the closest available resource, with use of lights-and-sirens travel to the scene. It is used for cases considered time critical due to a potential life-threatening situation. The target response time is 15 minutes or less for at least 90% of Priority 1 cases.
  SJWA generates a *dual-response Priority 1* for cases of cardiac arrest, i.e. whereby at least two ambulance crews are dispatched. These are, effectively, a *higher priority* Priority 1

call as a crew en-route to a standard Priority 1 can be diverted to a dual-response Priority 1 that has presented.

- **Priority 2:** Considered *Urgent* calls. These have an immediate dispatch where possible, with travel to the scene under normal road conditions. This priority is used for cases that are unlikely to be life threatening but require urgent assessment or management. An ambulance crew en-route to a Priority 2 call can be diverted to a Priority 1 call. The target response time is 25 minutes or less for at least 90% of Priority 2 cases.
- **Priority 3:** Considered *Non-urgent* or *routine* calls. These are cases with no time pressing need identified. An ambulance crew will be dispatched however this can be delayed. An ambulance crew en-route to a Priority 2 call can be diverted to a Priority 1 or 2 call. The target response time is 60 minutes or less for at least 90% of Priority 3 cases.

2.3.3. Emergency Calls

Emergency calls in Australia requiring attendance by police, fire or ambulance services, are all made to the national emergency number – Triple Zero (000). Triple Zero calls are answered by a designated Emergency Call Person (organisation) – currently Telstra[30], Australia's largest and previously government owned telecommunication company. The caller to 000 will be asked firstly which service (police, fire, or ambulance) they require, and then which state and town the emergency is in. After providing this information, the caller is connected to the appropriate emergency service for that location.

2.3.4. State Operations Centre

The SJWA State Operations Centre (SOC) receives all 000 ambulance calls for Western Australia. Upon a 000 call being transferred to the SOC it is answered by a non-clinician Emergency Medical Dispatcher (EMD).

The EMD will ask the caller questions firstly to ascertain the location of the emergency, then conduct a rapid telephone triage interview in order to triage the ambulance response. SJWA use the Medical Priority Dispatch System (MPDS) to conduct this triage. This is implemented with the ProQA software[31], which is connected to SJWA's bespoke Computer Aided Dispatch (CAD) system.

Once the EMD has gained sufficient information through the triage process using the questions in the MPDS, a dispatch code is generated indicating the nature of the call. This code from MPDS is mapped through a matrix to a priority allocation pre-determined by SJWA. Further information on the MPDS including this process is detailed later in this chapter.

After the priority required for the response is automatically determined, the call will be saved into CAD and appear on a dispatch terminal to be allocated to ambulance crew(s) as appropriate. When a call is allocated to an ambulance crew in the Perth metropolitan area, the crew are contacted to advise of the call. Details of the call such as the address and any access instructions, any safety concerns, and basic details of the triage including the dispatch coding and description are sent to a mobile data terminal within the ambulance to facilitate the crew responding to the call and preparing for the medical situation they are responding to.

2.3.5. Secondary Triage

Since 2020 (after the time period for my studies), SJWA has employed a process of secondary triage targeting Priority 3 calls. This follows similar secondary triage processes introduced in other Australasian jurisdictional ambulance services. A dedicated team of clinicians within the SOC including General Practitioners, registered paramedics and more recently registered nurses, conduct further and more detailed telephone clinical assessments for patients triaged as non-urgent before they are dispatched to an ambulance crew. Secondary triage clinicians firstly ensure that patients who may have a more urgent condition have not been missed by the primary triage process (and upgrade the call's priority if they have concerns), but then where appropriate refer the patient to alternative health care pathways such as primary care if they do not have an apparent need for ambulance or hospital Emergency Department presentation.

2.3.6. Electronic Patient Care Records

SJWA paramedics complete a patient care record for every patient encounter. These are in the form of an Electronic Patient Care Record (ePCR) using an application developed within SJWA. Paramedics use an Apple iPad to complete the ePCR, and the data are stored within SJWA information technology environment.

The ePCR as completed by the paramedic includes fields for patient demographics, medical history, assessments, observations, and interventions, as well as free text to document assessment and management. These fields can all be queried to obtain overall data.

2.4. Medical Priority Dispatch System

2.4.1. Overview

The Medical Priority Dispatch System (MPDS) is a proprietary primary triage system for emergency medical calls designed to rapidly triage an emergency call based on questions about the patient's presenting problem and symptoms. It is used in all Australasian ambulance services other than the Australian Capital Territory, including SJWA, and is widely used internationally. It has been translated into multiple languages. Localised versions are available for different regions, for example the ANZ (Australia and New Zealand) version has specific codes for funnel web spider bites and marine envenomation not found in other locales[32].

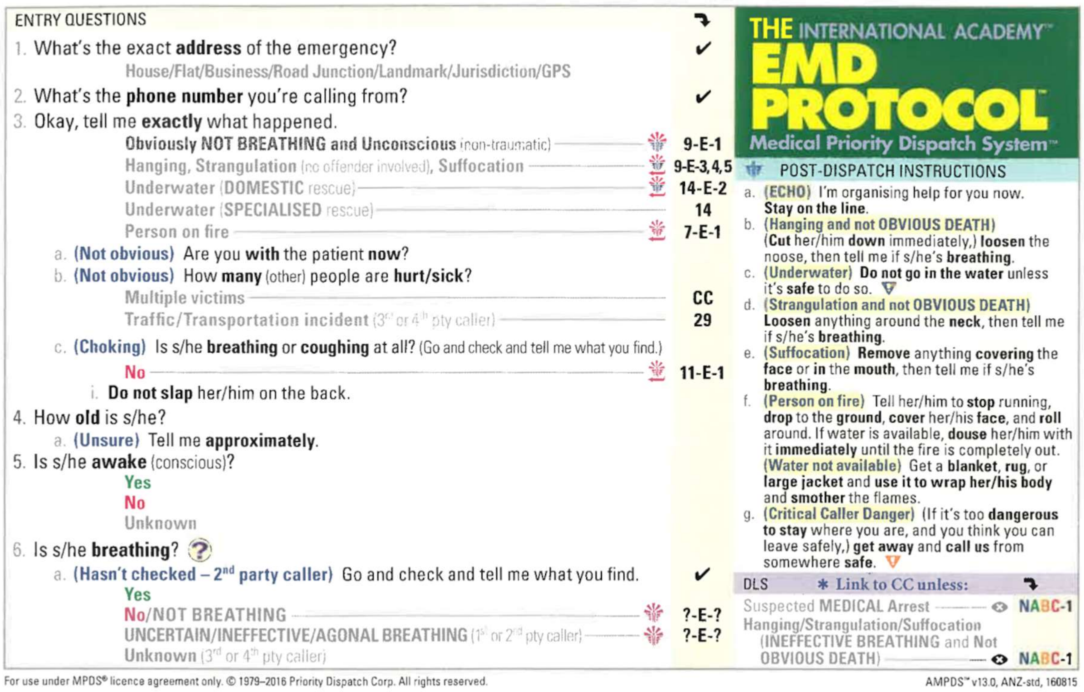
MPDS is a scripted algorithm that produces a dispatch code (known as a "determinant code") based on the patient's presentation. The ambulance service pre-determines the response to any given MPDS determinant code.

An EMD using MPDS will, after ascertaining the location of the emergency and a callback telephone number, ask the caller for a description of the problem with the prompt "tell me exactly what happened". After this the caller is asked for the number of patients (if not obvious), age, sex and whether the patient is awake (conscious) and breathing[12]. The EMD will then select the most appropriate protocol based on the nature of the presenting problem and ask further questions to produce a determinant – which in most systems including SJWA is immediately used by a CAD system to generate the appropriate response.

MPDS includes various diagnostic tools that become relevant for some patient conditions and may influence the final determinant, such as a stroke assessment, breathing rate assessment, and pulse assessment.

After triage questions are complete and a code generated, the caller is given further information by the EMD. This may include first aid advice where necessary (so-called Dispatch Life Support) which may include CPR instructions, bleeding control, positioning patients, use of adrenaline autoinjectors, airway obstruction/choking first aid and childbirth. For patients not requiring this level of emergency management on the telephone call, there are standard instructions to prepare for the arrival of paramedics and instructions to call back if there are any changes to the patient's condition[12].

Figure 1: Case Entry questions (asked at the beginning of the call for every caller) in MPDS[12]



The final determinant code produced is in the form of *XX-Y-ZZ-S*, where:

- X is a number indicating the relevant MPDS protocol
- Y is a letter indicating the acuity level of the call
- Z is the determinant number within that protocol and acuity
- S is an optional suffix that denotes further information

These elements are discussed in Section 2.4.3 . Including all suffixes, there are 1,836 possible MPDS determinant codes.

During the study period, a single version of MPDS, version 13, was in use.

2.4.2. Priority Symptoms

MPDS protocols may have a number of specific questions relevant to the particular protocol indicate a high priority patient, for example mechanism of injury on trauma-related protocols, or neurological symptoms on the headache and stroke protocols. In general, however there are four key symptoms (known as "priority symptoms") that MPDS has identified that EMDs should prioritise for assessment if they are identified at any point in the call. These are chest pain, breathing problems, altered conscious states and serious bleeding. It is considered that any high acuity patient will eventually develop one of the above[33].

2.4.3. Structure

2.4.3.1. Protocol

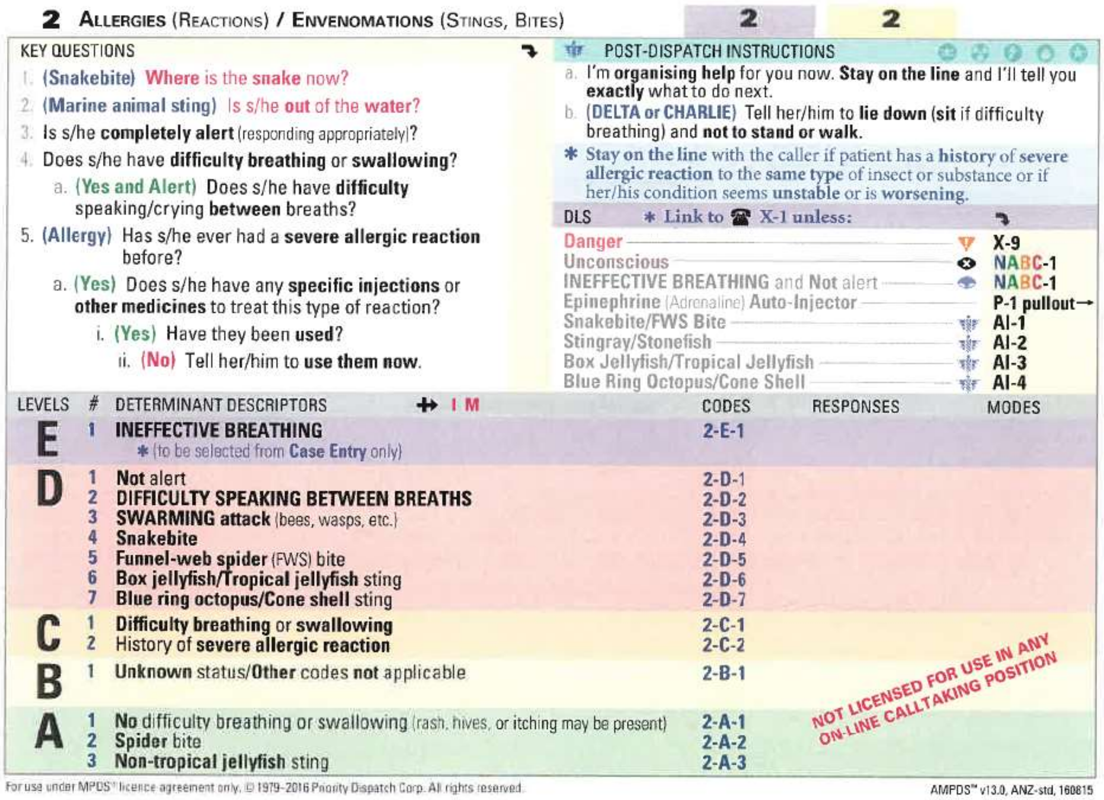
There are 32 standard protocols for emergency calls in the MPDS, each representing a "chief complaint" or reason for the call. A full list of these is shown in Table 2. Each protocol contains a list of key questions, and relevant determinant codes based on the answers to the questions. If, based on the answers to the questions, a different protocol would be more relevant, the system directs the EMD to move to that other protocol instead.

An example protocol with questions and determinant codes is shown in Figure 2.

Table 2: List of Protocols within Medical Priority Dispatch System v13 [12]

01 Abdominal pain/problems
02 Allergies (reactions)/Envenomations (stings, bites)
03 Animal bites/attacks
04 Assault/Sexual assault
05 Back pain (non-traumatic/non-recent trauma)
06 Breathing problems
07 Burns (scalds)/Explosion (blast)
08 Carbon monoxide/inhalation/HAZMAT/CBRN
09 Cardiac or respiratory arrest/death
10 Chest pain (non-traumatic)
11 Choking
12 Convulsions/Fitting
13 Diabetic problems
14 Drowning (near)/Diving/SCUBA accident
15 Electrocution/Lightning
16 Eye problems/injuries
17 Falls
18 Headache
19 Heart problems/AICD
20 Heat/Cold exposure
21 Haemorrhage/Lacerations
22 Inaccessible incident/Other entrapments (non-vehicle)
23 Overdose/Poisoning (ingestion)
24 Pregnancy/Childbirth/Miscarriage
25 Psychiatric/Abnormal behaviour/Suicide attempt
26 Sick person (specific diagnosis)
27 Stab/Gunshot/Penetrating trauma
28 Stroke (cerebrovascular accident)
29 Traffic/Transportation incidents
30 Traumatic injuries (specific)
31 Unconscious/Fainting (near)
32 Unknown problem

Figure 2: Example MPDS Protocol (Allergies/Envenomations)[12]



2 ALLERGIES (REACTIONS) / ENVENOMATIONS (STINGS, BITES) **2** **2**

KEY QUESTIONS

1. (Snakebite) Where is the snake now?
2. (Marine animal sting) Is s/he out of the water?
3. Is s/he **completely alert** (responding appropriately)?
4. Does s/he have **difficulty breathing** or **swallowing**?
   a. (Yes and Alert) Does s/he have **difficulty** speaking/crying **between** breaths?
5. (Allergy) Has s/he ever had a **severe allergic reaction** before?
   a. (Yes) Does s/he have any **specific injections** or **other medicines** to treat this type of reaction?
      i. (Yes) Have they been **used**?
      ii. (No) Tell her/him to **use them now**.

POST-DISPATCH INSTRUCTIONS

a. I'm **organising help** for you now. **Stay on the line** and I'll tell you **exactly** what to do next.
b. (DELTA or CHARLIE) Tell her/him to **lie down** (**sit** if difficulty breathing) and **not to stand or walk**.

✱ Stay on the line with the caller if patient has a **history** of **severe allergic reaction** to the same **type** of insect or substance or if her/his condition seems **unstable** or is **worsening**.

DLS ✱ Link to X-1 unless:

Danger	X-9
Unconscious	NABC-1
INEFFECTIVE BREATHING and Not alert	NABC-1
Epinephrine (Adrenaline) Auto-Injector	P-1 pullout→
Snakebite/FWS Bite	AI-1
Stingray/Stonefish	AI-2
Box Jellyfish/Tropical Jellyfish	AI-3
Blue Ring Octopus/Cone Shell	AI-4

LEVELS	#	DETERMINANT DESCRIPTORS	CODES	RESPONSES	MODES
E	1	**INEFFECTIVE BREATHING** ✱ (to be selected from **Case Entry** only)	2-E-1		
D	1	**Not** alert	2-D-1		
	2	**DIFFICULTY SPEAKING BETWEEN BREATHS**	2-D-2		
	3	**SWARMING attack** (bees, wasps, etc.)	2-D-3		
	4	**Snakebite**	2-D-4		
	5	**Funnel-web spider** (FWS) bite	2-D-5		
	6	**Box jellyfish/Tropical jellyfish** sting	2-D-6		
	7	**Blue ring octopus/Cone shell** sting	2-D-7		
C	1	**Difficulty breathing** or **swallowing**	2-C-1		
	2	History of **severe allergic reaction**	2-C-2		
B	1	**Unknown** status/**Other** codes **not** applicable	2-B-1		
A	1	**No** difficulty breathing or swallowing (rash, hives, or itching may be present)	2-A-1		
	2	**Spider** bite	2-A-2		
	3	**Non-tropical jellyfish** sting	2-A-3		

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AMPDS™ v13.0, ANZ-std, 160815

2.4.3.2. Level

Within each protocol there are multiple determinants, divided up into levels. The levels are effectively an acuity level, listed from highest to lowest acuity. Each acuity level is associated with an ideal (based on a North American EMS model) response mode, but this is not a requirement of MPDS to align these dispatch modes as this depends on individual services.

The determinant levels in MPDS, with their notional response (as proposed by the MPDS) are:

- **ECHO** (E): Rapid dispatch (when identified as an echo-level problem, calls on these codes are dispatched immediately after the question of "tell me exactly what happened" identifies the problem prior to going through the remainder of the question sequence), send the closest available resource of any type along with Advance Life Support (ALS) running lights and sirens
- **DELTA** (D): ALS dispatch lights and sirens in addition to any standard Basic Life Support (BLS) response

- **CHARLIE** (C): ALS dispatch normal road speed in addition to any standard BLS response
- **BRAVO** (B): BLS dispatch lights and sirens
- **ALPHA** (A): BLS dispatch normal road speed
- **OMEGA** (O): Indicates a code that may be low acuity enough to not require ambulance dispatch at all

2.4.3.3. Determinant codes

Each protocol has a number of mutually exclusive determinant codes (i.e. each emergency call is assigned a single determinant code), with the choice of determinant code being based on the answers to the key questions. Determinant codes are arranged into acuity levels within the individual MPDS protocol, and then further ranked by acuity within each level. The highest relevant determinant code based on the answers given to the key questions is allocated to the call.

For example, on the protocol shown in Figure 2, a patient who is described as having an allergic reaction and presenting with a rash, with no difficulty breathing or swallowing, and being alert, would be coded with a 2-A-1 determinant code. If that patient had difficulty swallowing, they would be coded as 2-C-1, and likely receive a higher priority response as determined by the relevant ambulance service. If the patient was reported to not be completely alert when asked that key question, they would receive a 2-D-1 code, regardless of their answer to the question about swallowing difficulty. Thus, in this example, different symptoms (being not alert; having difficulty swallowing; presenting with a rash) have an inherent hierarchy in how the MPDS proposes that patient acuity is determined[34]. Notably, for this protocol, as with the majority of MPDS protocols, the classification of the patient as not alert tends to rank highly for patient acuity.

2.4.3.4. Determinant code suffix

MPDS codes on some protocols may have an additional suffix attached. This indicates further information that may affect the response required, and can be applied to any determinant within that protocol. Suffixes may include clinical or non-clinical information. For example, the Headache and Stroke protocols contain a stroke screening tool, and the outcome of this (stroke symptoms and time since onset) may affect the priority of the response. Conversely, the

Abnormal Behaviour protocol has suffixes indicating whether the patient is violent or armed with a weapon. These may not change the priority of clinical responders but may indicate the need for other services to assist such as police.

2.4.4. Dispatch response

Every ambulance service, or emergency medical service, defines their response to each MPDS determinant code. This response often takes the form of a response matrix which maps the determinant to the response. A service's response matrix will depend on their clinical model, resourcing arrangements, local health system, risk tolerance and other factors.

Different response models will also necessitate different response matrices between services. For example where SJWA has a single-tier service, the matrix needs only to nominate a priority. Other interstate and overseas services, however, who have Intensive Care or Critical Care Paramedics as part of their response model, will need to detail in their response matrix which determinants should receive a baseline level paramedic response and which should receive a higher tier response.

The levels in MPDS do not mandate a particular response. For example, a service may choose to give a high priority response to all chest pain determinants, even though there is an ALPHA level code within MPDS - 10-A-1 (chest pain, breathing normally, no cardiac history, age <35).

2.4.5. Conscious State determination in MPDS

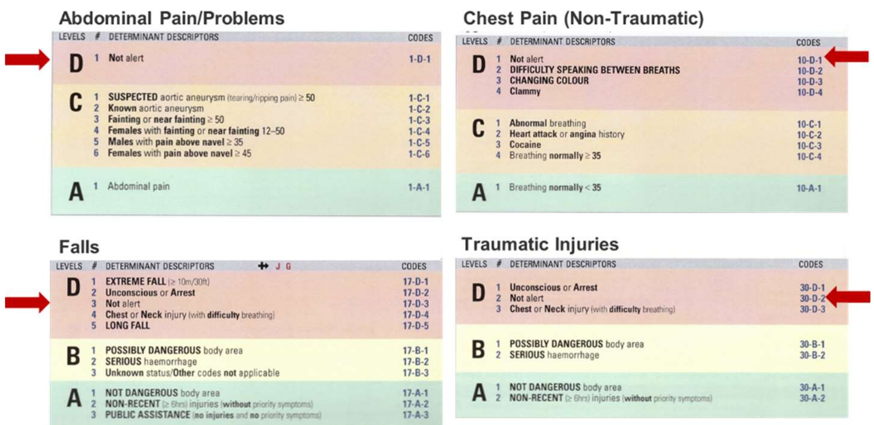
A patient's conscious state is determined in MPDS through two questions:

1. Firstly, in the case entry, there is a question "is [the patient] awake?" – a negative response indicating the patient is unconscious.
2. Secondly, in most (but not all) protocols there is a further question "is [the patient] completely alert?" – a negative response meaning the patient receives a 'Not Alert' determinant (unless there is a higher ranked determinant also relevant).
   Should the caller not understand this question or not give an unequivocal answer, an alternate clarifier question can be asked – "is [the patient] responding appropriately?"(12).

Thus, there is effectively a three-level conscious state determination in MPDS: Alert, Not Alert, Unconscious.

As stated earlier (section 2.4.2.3), 'Not Alert' determinant codes tend to be ranked very high within their individual protocols, and always at DELTA level, thus they generate high priority responses. Some examples of this are shown in Figure 3.

Figure 3: Examples of the ranking of 'Not Alert' determinants in selected protocols[12]



Abdominal Pain/Problems

LEVELS	#	DETERMINANT DESCRIPTORS	CODES
D	1	Not alert	1-D-1
C	1	SUSPECTED aortic aneurysm (tearing/ripping pain) ≥ 50	1-C-1
	2	Known aortic aneurysm	1-C-2
	3	Fainting or near fainting ≥ 50	1-C-3
	4	Females with fainting or near fainting 12–50	1-C-4
	5	Males with pain above navel ≥ 35	1-C-5
	6	Females with pain above navel ≥ 45	1-C-6
A	1	Abdominal pain	1-A-1

Chest Pain (Non-Traumatic)

LEVELS	#	DETERMINANT DESCRIPTORS	CODES
D	1	Not alert	10-D-1
	2	DIFFICULTY SPEAKING BETWEEN BREATHS	10-D-2
	3	CHANGING COLOUR	10-D-3
	4	Clammy	10-D-4
C	1	Abnormal breathing	10-C-1
	2	Heart attack or angina history	10-C-2
	3	Cocaine	10-C-3
	4	Breathing normally ≥ 35	10-C-4
A	1	Breathing normally < 35	10-A-1

Falls

LEVELS	#	DETERMINANT DESCRIPTORS J G	CODES
D	1	EXTREME FALL (≥ 10m/30ft)	17-D-1
	2	Unconscious or Arrest	17-D-2
	3	Not alert	17-D-3
	4	Chest or Neck injury (with difficulty breathing)	17-D-4
	5	LONG FALL	17-D-5
B	1	POSSIBLY DANGEROUS body area	17-B-1
	2	SERIOUS haemorrhage	17-B-2
	3	Unknown status/Other codes not applicable	17-B-3
A	1	NOT DANGEROUS body area	17-A-1
	2	NON-RECENT (≥ 6hrs) injuries (without priority symptoms)	17-A-2
	3	PUBLIC ASSISTANCE (no injuries and no priority symptoms)	17-A-3

Traumatic Injuries

LEVELS	#	DETERMINANT DESCRIPTORS	CODES
D	1	Unconscious or Arrest	30-D-1
	2	Not alert	30-D-2
	3	Chest or Neck injury (with difficulty breathing)	30-D-3
B	1	POSSIBLY DANGEROUS body area	30-B-1
	2	SERIOUS haemorrhage	30-B-2
A	1	NOT DANGEROUS body area	30-A-1
	2	NON-RECENT (≥ 6hrs) injuries (without priority symptoms)	30-A-2

Terms appearing in all-capitals within an MPDS protocol have a specific definition in MPDS[33]. This is not the case for "Not alert". There may be some indication of the intention of this in the question "Is [the patient] completely alert?", however there may be another understanding of this based on a defined term within one of the MPDS protocols. Protocol 26 (Sick Person) is used where the caller describes a condition not captured by another protocol (and usually used for low acuity conditions, as priority symptoms identified will be shunted to a relevant protocol). Within this protocol there is a further defined conscious state level known as "altered level of consciousness". This is used when a caller uses any of a list of descriptors to describe the patient's conscious state when asked the alertness question. These descriptors are shown in Table 3. Patients meeting this definition receive a CHARLIE level determinant (26-C-1) whereas any other altered conscious state receives a DELTA level determinant (26-D-1). This would indicate that patients with these descriptors are considered less acute than, and do not meet the definition of, Not Alert.

Table 3: List of "Altered level of consciousness" descriptors on MPDS Protocol 26[12]

Combative	Lethargic	Not with it
Confused	Non-/unresponsive	Out of it
Dazed	Not acting normal	Semi-conscious
Delirious	Not acting right	Slurred speech
Disoriented	Not aware	Won't respond
Incoherent	Not thinking right	

Given these ambiguities about distinguishing Alert from Not Alert in emergency calls, I performed a sensitivity analysis in Chapter 5 of this thesis, by varying the threshold applied to classifying Alert versus Not Alert patients based on paramedic-determined conscious state. Chapter 6 further addresses the significance of the threshold between Alert and Not Alert patients by examining the relationship between different levels of paramedic-determined altered conscious state and patient acuity.

2.5. Measures of conscious state

There are various approaches used by health professionals to measure and report a patient's conscious state. Because conscious state exists on a spectrum, most measures use either a descriptive scale or numerical score.

The **Glasgow Coma Scale (GCS)**, developed in 1974 by Teasdale and Jennett[35], is a numerical scale used for measuring conscious state. It was designed for use in a neurosurgical intensive care unit for patients with brain injuries, however, has been adopted for use throughout clinical care, and is the scale that most others are compared to. The scale is made up of an aggregated score on three subscales. The three subscales are for eye opening (score 1-4), verbal response (score 1-5), and motor response (score 1-6). A completely alert and responsive patient will receive the full score on each subscale (4, 5 and 6) for a total score of 15, whereas a completely unresponsive will receive the lowest score on each subscale (1, 1 and 1) for a total score of 3. The subscales for the GCS are shown at Table 4.

Table 4: Scoring components of the Glasgow Coma Scale

Best eye response	Best verbal response	Best motor response
1. None	1. None	1. None
2. Eyes open to pain	2. Incomprehensible sounds	2. Abnormal extension to pain
3. Eyes open to voice	3. Inappropriate words	3. Abnormal flexion to pain
4. Eyes open spontaneously	4. Confused	4. Withdrawal from pain
	5. Oriented	5. Localising pain
		6. Obeys commands

The **AVPU** scale is frequently used as a rapid conscious state assessment. It is a four-level descriptive categorical scale where a patient's conscious state can be described as Alert, Voice Response, Pain Response or Unresponsive. The AVPU scale is used for initial triage in an emergency setting (for example by paramedics in the prehospital setting on arrival to a patient as part of a primary survey, or by a triage nurse on a patient's arrival at an Emergency Department), along with ongoing assessment (for example AVPU often appears in inpatient observation charts). AVPU is recommended for initial triage in Advanced Trauma Life Support(15).

A similar scale, **ACDU**, is used in some intensive and critical care settings. Like AVPU it is a four-level descriptive categorical scale, in this case Alert, Confused, Drowsy, Unresponsive.

AVPU and ACDU descriptors have been aligned to ranges of GCS scores(36), with significant overlap both between descriptors on the same scale and between the Voice Response/Pain Response on AVPU and Drowsy/Confused on ACDU. It has been noted however that the ACDU scale has more utility to note subtle conscious state deterioration, whereas AVPU has better ability to describe greater neurological dysfunction(36).

2.5.1. St John WA recording of conscious state

SJWA paramedics record conscious state in two ways in ePCR:

1. An on-arrival conscious state, recorded in the "Response" section of the primary survey. This takes the form of a six-level descriptive categorical scale – Alert, Confused, Drowsy, Voice Response, Pain Response, Unresponsive. This is effectively a combination of the ACDU and AVPU scales. While there is overlap in these descriptors and their alignment

with GCS when used as individual scales[36], SJWA use the combined system in a hierarchical approach.

2. A GCS is completed and recorded with each formal set of observations (vital signs). A set of observations should be recorded as part of initial patient assessment, however with a patient that requires immediate management based on findings in a primary survey, a first set of observations may take place subsequent to initial management and thus not be a true reflection of the initial state of the patient.

2.6. Conclusion

This chapter provided context and background to the research conducted as part of this thesis, including both the setting (Western Australia) where the research occurred along with the internationally used telephone triage system used by the ambulance service in Western Australia.

Chapter 3. Concept and Methodological Overview

This chapter provides an overview of the overall concept of the research, along with the basic principles of the methodology for each research output produced as part of this thesis. It describes the research ethics for the overall project along with an overview of the study design, analysis and statistical or other methods used for each study.

There is also further detail on methodology including the setting, data sources, inclusion and exclusion criteria and statistical methods used within each chapter containing research outputs. Descriptions of rationale and considerations for decisions that were made on methods are also located within these individual chapters.

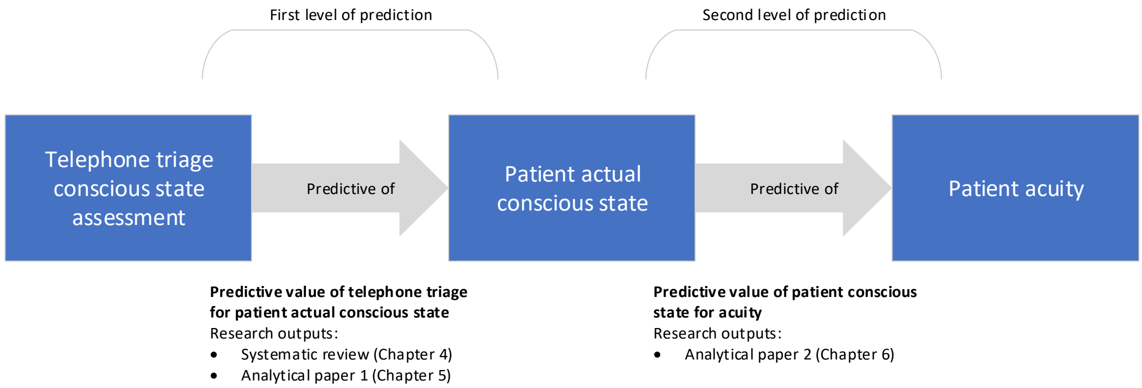
3.1. Overall concept

Triage systems aim to be predictive of a patient's urgency or acuity, so that the patients with the most time sensitive health care needs are seen first. As discussed in the Introduction chapter, a patient's conscious state is routinely used in triage, and is thus considered (amongst other clinical indicators) a predictor of their acuity. One can study the utility of this by analysing the predictive value of a patient's conscious state at the point of triage in relation to their actual acuity.

In the setting of telephone triage, there is another element to consider when analysing triage. While conscious state may be reflective of patient acuity, there is a question of how accurately telephone triage assessment of conscious state predicts the patient's actual conscious state.

Thus, there are effectively three variables to consider: (1) conscious state determination on the emergency call, (2) patient actual conscious state, and (3) patient actual acuity. This means there are two layers of predictive value to be analysed in the aim of best predicting patient acuity with assessment of conscious state on emergency calls – accuracy of assessment of conscious state, then predictive value of conscious state of patient acuity. This concept is illustrated in Figure 4.

Figure 4: Thesis concept



Accuracy of conscious state in telephone triage is primarily about the first level of prediction, that is, how predictive is the conscious state assessment on the emergency call, of the patient's actual conscious state on the arrival of responding clinicians? This concept is addressed in both my systematic review (Chapter 4) and first analytical paper reviewing accuracy of assessment of patient conscious state in emergency calls (Chapter 5).

While it doesn't directly involve telephone triage, understanding the relationship between the patient's actual conscious state and their acuity (i.e. the second level of prediction) is important as it may lead to an understanding of clinically significant levels of consciousness, which can inform better questioning in telephone triage. This concept is addressed in my second analytical paper investigating the relationship between patient conscious state and acuity in ambulance attendances (Chapter 6).

3.2. Ethics

This M.Phil project sits under an overarching study titled "The Western Australian Pre-hospital Care Record Linkage Project", for which I am listed as a co-investigator. Specific ethics approval was given for this M.Phil project by the Curtin University Human Research Ethics Committee (HR128/2013-46). Approval was granted by the SJWA Research Governance Committee to access CAD data and patient care records. These were managed by PRECRU under strict data security protocols.

Records used for analysis did not contain any personal identifiers, and any SJWA case identifiers were replaced with PRECRU specific identifiers such that they could not be directly re-linked to other SJWA data.

3.3. Research output 1: Systematic Review into accuracy of telephone assessment of conscious state

I performed a systematic review into the accuracy of telephone triage of conscious state. This was designed to look at the first layer of prediction in the above model – conscious state assessment on the emergency call as a predictor of the patient's actual conscious state.

The study question was defined as: **In the setting of an emergency call to an emergency medical service (EMS), does the call-taker's determination of a patient's level of consciousness accurately predict the patient's level of consciousness as found by EMS responders?**

This study was published as:

Belcher J, Finn J, Whiteside A, Ball SJ. Accuracy of call-taker assessment of patient level of consciousness: a systematic review. *Australasian Journal of Paramedicine*. 2020;17:1-9. doi:10.33151/ajp.17.741[37].

The published manuscript including the methodology is reproduced in Chapter 4, along with a further review of literature published since this review was conducted. This chapter also includes a detailed methodology which comments rationale for decisions made in the study design.

3.4. Research output 2: Analysis of accuracy of EMD assessment of conscious state

My second research output was an analysis of the accuracy of telephone triage of conscious state. Like the systematic review, this was designed to look at the first layer of prediction in the above model – conscious state assessment on the emergency call as a predictor of the patient's actual conscious state on arrival of responders.

The study was a retrospective observational study of the association between Emergency Medical Dispatcher (EMD) determined patient conscious state (alertness, as per the question asked in MPDS), and conscious state findings by paramedics on arrival at scene. It was a population study of all patients in the Perth metropolitan area for whom an emergency ambulance call was made in a 1-year period. Patients were categorised as either *Alert* or *Not Alert* for each of EMD and paramedic assessment.

Based on these categories, the following measures of diagnostic accuracy were calculated:

- **Sensitivity:** proportion of paramedic determined Not Alert patients also determined as Not Alert by EMD
- **Specificity:** proportion of paramedic determined Alert patients also determined as Alert by EMD
- **Positive Predictive Value (PPV):** proportion of EMD-determined Not Alert patients also determined as Not Alert by paramedics
- **Negative Predictive Value (NPV):** proportion of EMD-determined Alert patients also determined as Alert by paramedics

These are demonstrated in the matrix shown in Figure 5. The overall results were also shown on a matrix of this nature.

Figure 5: Measures of diagnostic accuracy for conscious state determination

		Paramedic assessment on arrival	
		Not Alert	Alert
EMD assessment	Not Alert	True Positive (TP)	False Positive (FP)
	Alert	False Negative (FN)	True Negative (TN)
		Sensitivity = TP/(TP + FN) % of not-alert patients on scene who were dispatched not-alert	Specificity = TN/(FP + TN) % of alert patients on scene who were dispatched as alert

Positive Predictive Value (PPV) = TP/(TP + FP)
% of patients dispatched not-alert who were not-alert on scene

Negative Predictive Value (NPV) = FN/(FN + TN)
% of patients dispatched as alert who were alert on scene

These results were reported for the whole dataset, and also stratified by MPDS protocol (broad presenting problem or reason for the emergency call) to determine if there were differences in accuracy between different types of calls.

This study was published as:

Belcher J, Finn J, Whiteside A, Ball S. 'Is the patient completely alert?' – accuracy of emergency medical dispatcher determination of patient conscious state. *Australasian Journal of Paramedicine*. 2021;18:1-10. doi:10.33151/ajp.18.858[38].

The published manuscript is reproduced in Chapter 5 along with detailed methodology and rationale for features of the study design. Along with the study published in the manuscript, Chapter 5 also includes additional analysis based on an alternative threshold of Alert versus Not Alert for paramedic assessment due to ambiguity in the definition of "Not Alert".

3.5. Research output 3: Analysis of relationship between conscious state and acuity

My third research output was an analysis of the relationship between the patient's initial presenting conscious state as assessed by paramedics on arrival, and whether they were a high acuity patient. This study was designed to look at the second layer of prediction in the model of the overall thesis – patient conscious state at the scene as a predictor of their acuity.

The rationale for this study was to identify if there is an appropriate level of consciousness that is most informative in predicting patient acuity, that could be applied in the emergency dispatch triage context. This analysis was motivated by my analyses in Chapter 5, of using (as a sensitivity analysis) two alternative definitions of paramedic-determined alertness, in relation to ambiguity in the interpretation of "Not Alert". While this study does not directly assess telephone triage, my intention was that it could be informative for that setting in that an understanding of the relationship between conscious state and patient acuity could help shape the questions asked about conscious state in emergency calls. The study was a retrospective observational study of the association between paramedic determined conscious state on arrival to a patient, and their prehospital acuity based on paramedic assessment and management. This was a population study of all patients attended by paramedics in the Perth metropolitan area in a 1-year period.

Patient acuity was assessed based on indicators within patient care records such as paramedic assessment or management that would indicate a high acuity patient, following the High Acuity Filter process proposed by Andrew et al[9] for aligning ambulance dispatch priority to patient acuity. Patients were considered high acuity if their care record contained any of the indicators in the High Acuity Filter, and lower acuity otherwise.

Each on-arrival level of consciousness as selectable by paramedics (Alert, Confused, Drowsy, Voice Response, Pain Response, Unresponsive) was treated as a threshold level (i.e. for each level as a threshold, the numbers would include patients with that level of consciousness *and below*). The following measures of diagnostic accuracy were calculated using each level of consciousness as a threshold:

- **Sensitivity:** proportion of high acuity patients who presented with a conscious state at or below the selected threshold level.
- **Specificity:** proportion of lower acuity patients who did not have a conscious state at or below the selected threshold level.
- **Positive Predictive Value (PPV):** proportion of patients with a conscious state at or below the selected threshold level who were high acuity.
- **Negative Predictive Value (NPV):** proportion of patients without a conscious state at or below the selected threshold level who were lower acuity.

The calculation of these measures is illustrated in Figure 6.

Figure 6: Measures of diagnostic accuracy for conscious state prediction of patient acuity

		Patient acuity		
		High Acuity	Lower Acuity	
Patient conscious state	At or below threshold level	True Positive (TP)	False Positive (FP)	Positive Predictive Value (PPV) = TP/(TP + FP) Proportion of high acuity patients who presented with a conscious state at or below the selected threshold level.
	Above threshold level	False Negative (FN)	True Negative (TN)	Negative Predictive Value (NPV) = FN/(FN + TN) Proportion of lower acuity patients who did not have a conscious state at or below the selected threshold level.
		Sensitivity = TP/(TP + FN) Proportion of patients with a conscious state at or below the selected threshold level who were high acuity.	Specificity = TN/(FP + TN) Proportion of patients without a conscious state at or below the selected threshold level who were lower acuity.	

I determined the proportion of high acuity patients (i.e. the positive predictive value) at each threshold level to demonstrate if there was a particular point at which the PPV had a large increase that may indicate an appropriate threshold level to use for conscious state questioning. This analysis was conducted on the data set as a whole, and then stratified by each individual case's MPDS code as there may be significant differences with different types of patient presentations.

For the final part of this analysis, I sought to determine how predictive conscious state (measured as a 6-level variable) is, of patient acuity. I constructed a Receiver Operating Characteristics (ROC) curve, measuring the Area Under the Curve (AUC) for the whole data set and then stratified by each individual MPDS protocol for the individual cases. I ranked the AUC for each MPDS protocol to demonstrate which protocols (or types of patient presentations) conscious state is most predictive of acuity.

This study was published in the Australasian Emergency Care journal:
Belcher J, Finn J, Whiteside A, Ball S. Association between initial presenting level of consciousness and patient acuity – A potential application for secondary triage in emergency ambulance calls. *Australasian Emergency Care*. 2023;26(3):199-204. doi:10.1016/j.auec.2022.11.002[39].

This manuscript is presented in Chapter 6. As with the other studies, I have included a detailed methodology including rationale for key decisions in the study design within Chapter 6.

3.6. Conclusion

This chapter has introduced the studies and research outputs that comprise my thesis, along with the overall concept to demonstrate how they inter-relate. I have given an overview of the methodology and study design for each study, with detailed methodologies included within the chapters containing these research outputs.

The following chapters will introduce and give further detail of the three research outputs that were produced for the thesis.

Chapter 4. Systematic review

4.1. Overview

In this chapter, I present a systematic review of the literature performed to understand, investigate and synthesise the reported evidence regarding the association between conscious state assessment in an emergency call and on arrival of EMS responders. I searched across four databases – MEDLINE, EMBASE, CINAHL and Scopus for studies that reported any measure of conscious state on an emergency call and compared to findings at the scene. The full methodology is described in the published manuscript.

Prior to conducting the review, I registered the protocol with PROSPERO, the international prospective register of systematic reviews[40], with registration number CRD42019116403. A copy of the registration is included in Appendix 1.

My findings are reported in the following manuscript that was published in the *Australasian Journal of Paramedicine* in 2020:
Belcher J, Finn J, Whiteside A, Ball SJ. Accuracy of call-taker assessment of patient level of consciousness: a systematic review. *Australasian Journal of Paramedicine*. 2020;17:1-9. doi:10.33151/ajp.17.741[37].

The published manuscript is reproduced after the detailed methodology. As the *Australasian Journal of Paramedicine* is an open-access journal, no permission was required for its reproduction.

4.2. Detailed Methodology

The published manuscript which includes the methodology for the study is reproduced after this section. In this section I have expounded on some key features of the methodology including rationale for some choices in the study design.

4.2.1. Study question

The study question was defined as: **In the setting of an emergency call to an emergency medical service (EMS), does the call-taker's determination of a patient's level of**

consciousness accurately predict the patient's level of consciousness as found by EMS responders?

This question was based on the PICO model[41, 42] as follows:

Population: Patients in the community for whom an ambulance is called

Intervention/Index test: Call-taker determination of patient conscious state

Comparison/Reference test: Findings of conscious state by responder attending the patient

Outcome: Measures of diagnostic accuracy of call-taker determination

4.2.2. Inclusion criteria

Studies were included if they dealt with a call to an emergency medical service for a patient in the community, reported the patient's assessed level of consciousness, and compared this to level of consciousness on arrival of responders.

I defined patients in the community as a patient not already in the health system, so a study dealing with interhospital transfers would not be included. My aim with this definition was to capture the assessment when dealing with a layperson caller, not a health professional who could directly report an accurate conscious state assessment. Ultimately, however, this criterion did not end up excluding any potential studies.

I defined a responder as any person responding as part of the emergency medical system. That may include health professionals such as paramedics, doctors or nurses, or other rescuers such as volunteers, police officers or firefighters – so long as they had an ability to assess and record a level of consciousness. There was no restriction on how this assessment should be performed or reported.

I required any included study to report at least one measure of diagnostic accuracy, or data that would enable at least one measure to be calculated. While studies that described conscious state assessment in emergency calls may be informative, measures of diagnostic accuracy were required to be able to assess accuracy and perform potential meta-analysis.

I did not apply any restriction as to dates or language as part of the review.

4.2.3. Search strategy and data sources

My search strategy was deliberately very broad to capture as many potential articles as possible. The search strategy was developed in conjunction with a Curtin University librarian.

The search strategy looked for articles matching concepts of:

> **emergency medical services** AND
>
> **conscious state** AND
>
> **triage** OR **accuracy**

For each concept I found disparate keywords used throughout the literature on my preliminary searches, so a wide range of search terms for each concept was used to capture the breadth of literature as much as possible. Likewise, the strategy of searching for *either* triage or accuracy was designed to capture a broad range of potential literature. I expected this would return a large number of articles to sort through, however given the scarcity of literature in my initial searches, this seemed reasonable to ensure I captured as much as possible with the search strategy.

The full search strategy including key words is shown in Table 5.

MEDLINE, EMBASE, CINAHL and Scopus databases were searched using this strategy, and reference lists for included articles were also searched to locate any additional resources.

Table 5: MEDLINE search strategy

1. "emergency medical services"
2. EMS
3. EMT
4. "emergency medical technician"
5. paramedic
6. ambulance
7. prehospital
8. pre-hospital
9. "Emergency Medical Services"/
10. exp Emergency Medical Services/
11. exp Ambulances/
12. 1 or 2 or 3 or 4 or 5 or 6 or 7 or 8 or 9 or 10 or 11
13. awareness/ or comprehension/
14. GCS
15. "glasgow coma"
16. "avpu"
17. "altered conscious state"
18. "conscious state"
19. alertness
20. alert or conscio* or cognit* or awake
21. "Unconscious (Psychology)"/
22. "CONSCIOUSNESS DISORDERS"/ or exp CONSCIOUSNESS/
23. "Consciousness Disorders"/ or "Brain Injuries"/
24. 13 or 14 or 15 or 16 or 17 or 18 or 19 or 20 or 21 or 22 or 23
25. "call handler"
26. "call taker"
27. "calltaker"
28. telephone. Or TELEPHONE/
29. triage or TRIAGE/
30. exp "EMERGENCY MEDICAL DISPATCH"/ or dispatch
31. exp "Emergency Medical Service Communication Systems"/
32. Communication/ or Triage/ or Hotlines/ or Telephone/
33. 25 or 26 or 27 or 28 or 29 or 30 or 31 or 32
34. reliability
35. accuracy
36. exp "reproducibility of results"/
37. accurate
38. agreement
39. concordance
40. inter-rater
41. 34 or 35 or 36 or 37 or 38 or 39 or 40
42. 12 and 24 and 33
43. 12 and 24 and 41
44. 42 or 43

4.2.4. Study selection, data collection and extraction

I performed the database searches, and I and my principal supervisor (SB) independently reviewed titles and abstracts to produce a shortlist, then reviewed full-text of potential studies to determine if they met eligibility criteria. Consensus was reached by discussion for any uncertainties.

For included studies I extracted and reported the following data:

- Study setting (location and year)
- Study design
- Outcome measure (and definition)
- Call-taker qualification
- EMS responder qualification
- Number of cases
- Data sources (for call-taker and EMS responder assessment)

I then reported for each study, measures of diagnostic accuracy (sensitivity, specificity, positive predictive value and negative predictive value). Where these metrics were not published within the studies, I calculated them from the raw data presented. I reported on as many of these measures of diagnostic accuracy as possible, based on the data available within each study.

4.2.5. Meta-analysis

I had intended to perform meta-analysis on the included studies if possible, however the nature of the studies included meant there was too much heterogeneity for this to be reasonable.

4.2.6. Reporting and registration

The review was conducted and reported according to the Preferred Reporting Items for Systematic Reviews and Meta-analysis (PRISMA) statement[43], and details of the protocol were prospectively registered on PROSPERO[40] (CRD42019116403).

4.2.7. Updated literature search

The initial literature search for this review was conducted in August 2018. A further literature search was performed on 18 July 2022 to find any more recently published literature indexed since the first literature search used for the published review. The same search strategy was used, and the same methodology applied as per the original review. Results of this are presented subsequent to the manuscript.

4.3. Manuscript

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Review

Accuracy of call-taker assessment of patient level of consciousness: a systematic review

Jason Belcher BSc is a MPhil candidate[1] and paramedic[2]; Judith Finn PhD is Director[1] and Adjunct Research Professor[2]; Austin Whiteside PGCert(EMS), AdvDipHSc(PrehospCare), is Operations Manager and paramedic[2]; Stephen Ball BSc, PhD is Research Fellow[1] and Adjunct Senior Research Fellow[2]

Affiliations:
[1]Prehospital, Resuscitation and Emergency Care Research Unit, Curtin University, Perth, Western Australia
[2]St John, Western Australia

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Abstract

Introduction

When triaging an emergency phone call for ambulance assistance, one of the key areas of questions asked in internationally used triage decision support systems is around the patient's level of consciousness. A patient with a reduced level of consciousness can be indicative of a requirement for a high level of urgency of ambulance response. However, the value of this as a triage criterion is dependent on how accurately it can be determined by the call-taker. We sought to identify and summarise the results from published studies which determine the accuracy of call-taker assessment of conscious state during an emergency phone call.

Methods

We searched MEDLINE, EMBASE, CINAHL and Scopus databases for studies relating to concepts of emergency medical services, conscious state, triage and/or accuracy. Studies were screened and included if they dealt with emergency calls in the community, reported call-taker determination and on-scene determination of conscious state, and included sufficient data for at least one measure of diagnostic accuracy to be calculated.

Results

Out of 5753 articles initially identified, only two were found that matched the inclusion criteria. Both reported accuracy of a binary determination of consciousness versus unconsciousness, and found that it is common for the reported consciousness to differ from actual findings at scene. There were no studies identified that measured accuracy of determination of altered conscious states among conscious patients.

Conclusion

There is a notable gap in the literature regarding accuracy of determination of the patient's conscious state in an emergency call, which needs to be addressed.

Keywords:
emergency dispatch; pre-hospital care; conscious state; triage; accuracy

Corresponding Author: Jason Belcher, jason.belcher@postgrad.curtin.edu.au

Background

In an emergency ambulance call, one of the key roles of the call-taker is to determine the nature of the emergency in order to prioritise the response, so that the right level of care is sent to the patient in the right timeframe. Ambulance services worldwide have reported inaccuracies in triage (1-7), in terms of both under-triage (ambulance dispatched at a lower priority than required) and over-triage (ambulance dispatched at a higher priority than required). Whereas under-triage may directly compromise the safety of the patients involved, reducing over-triage is also an important consideration so that ambulances remain available for those patients who have the greatest need for a high priority response (8,9).

Level of consciousness is an important criterion for triaging patients that is used in emergency medical dispatch systems around the world (10,11). Complete loss of consciousness may be indicative of a sudden severe medical condition or traumatic injury, and even in the absence of a highly acute cause, patients may be at risk of airway occlusion. In conscious patients, even reduced alertness (or reduced conscious state) can indicate a need for urgent attention, eg. due to hypoglycaemia, head trauma, stroke or poisoning. It is therefore reasonable that information about a patient's level of consciousness provides useful information about their need for urgent care. However, the value of this information in emergency ambulance calls relies on how accurately a patient's level of consciousness can be determined during calls, with inaccuracies having potentially important implications for ambulance services in terms of both under- and over-triage.

The purpose of this systematic review is to examine published studies to determine call-takers' accuracy to determine patients' level of consciousness in emergency calls to ambulance services.

Methods

This systematic review was conducted and reported according to the Preferred Reporting Items for Systematic Reviews and Meta-analysis (PRISMA) statement (12). Details of the protocol were registered on PROSPERO (13) (CRD42019116403).

Study question

The review question was: In the setting of an emergency call to an emergency medical service (EMS), does the call-taker's determination of a patient's level of consciousness accurately predict the patient's level of consciousness as found by EMS responders? This question was based on the PICO model (14,15): P (Population) = Patients in the community for whom an ambulance is called; I (Intervention/index test) = Call-taker determination of patient conscious state; C (Comparison/ reference test): Findings of conscious state by responder attending the patient; O (Outcome) = Measures of diagnostic accuracy of call-taker determination.

Inclusion criteria

Studies were included in the review if they: dealt with calls for help to an emergency medical service in the community; directly reported the call-taker's determination of the patient's level of consciousness; and directly compared call-taker determination of consciousness to the patient's level of consciousness as determined on arrival of EMS responders. For a study to be included, it had to report at least one measure of diagnostic accuracy, or provide data that enabled at least one measure of diagnostic accuracy to be calculated.

Callers were defined as 'in the community' if the call was a call for help for a patient not already in the health system (as opposed to, for example, a call to transfer an already-admitted patient from one facility to another). EMS responders were defined as any personnel responding as part of the emergency medical system; whether health professionals such as doctors, nurses or paramedics – or other rescuers such as volunteers, police officers or firefighters – so long as the rescuer had sufficient training to assess and record a patient's level of consciousness. No restrictions were applied in relation to dates or language.

Data sources

We searched MEDLINE, EMBASE, CINAHL and Scopus databases for studies. Reference lists for included articles were also searched to locate any additional resources. The search strategy looked for articles matching concepts of (a) emergency medical services AND (b) conscious state AND (c) triage OR accuracy. This strategy (particularly the inclusive approach of searching for 'triage OR accuracy') was designed to capture as many potentially relevant articles as possible. Preliminary searches of the literature found that disparate keywords were used for articles around this subject, so a wide range of search terms for these concepts were used to capture the breadth. The search strategy was developed in conjunction with a Curtin University librarian. The full MEDLINE search strategy is shown in Table 1.

Study selection

Author 1 (JB) performed the database searches. Duplicates were removed, and titles and abstracts were independently reviewed by Author 1 (JB) and Author 4 (SB) to locate potential studies. JB and SB then independently assessed the full text of potential studies to determine if eligibility criteria were met. Consensus was reached by discussion, for any disagreements or uncertainties.

Data collection process

Data was extracted from included studies onto a Microsoft Word table detailing: the study setting (location and year); study design; outcome measure (and definition); call-taker qualification; EMS responder qualification; number of cases; and data sources for call-taker and EMS responder assessment.

Table 1. MEDLINE search strategy

1. 'emergency medical services'
2. EMS
3. EMT
4. 'emergency medical technician'
5. paramedic
6. ambulance
7. prehospital
8. pre-hospital
9. 'Emergency Medical Services'/
10. exp Emergency Medical Services/
11. exp Ambulances/
12. 1 or 2 or 3 or 4 or 5 or 6 or 7 or 8 or 9 or 10 or 11
13. awareness/ or comprehension/
14. GCS
15. 'glasgow coma'
16. 'avpu'
17. 'altered conscious state'
18. 'conscious state'
19. alertness
20. alert or conscio* or cognit* or awake
21. 'Unconscious (Psychology)'/
22. 'CONSCIOUSNESS DISORDERS'/ or exp CONSCIOUSNESS/
23. 'Consciousness Disorders'/ or 'Brain Injuries'/
24. 13 or 14 or 15 or 16 or 17 or 18 or 19 or 20 or 21 or 22 or 23
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27. 'calltaker'
28. telephone. or TELEPHONE/
29. triage or TRIAGE/
30. exp 'EMERGENCY MEDICAL DISPATCH'/ or dispatch
31. exp 'Emergency Medical Service Communication Systems'/
32. Communication/ or Triage/ or Hotlines/ or Telephone/
33. 25 or 26 or 27 or 28 or 29 or 30 or 31 or 32
34. reliability
35. accuracy
36. exp 'reproducibility of results'/
37. accurate
38. agreement
39. concordance
40. inter-rater
41. 34 or 35 or 36 or 37 or 38 or 39 or 40
42. 12 and 24 and 33
43. 12 and 24 and 41
44. 42 or 43

Summary measures

Measures of diagnostic accuracy (sensitivity, specificity, positive predictive value and/or negative predictive value) were reported for each study (and calculated from raw data if required). Where 95% confidence intervals were not provided, they were calculated using Clopper-Pearson exact confidence intervals (16).

Quality and risk of bias

The QUADAS-2 tool for quality assessment of diagnostic studies (17) was used for assessment of quality and risk of bias. QUADAS-2 rates risk of bias (as 'low', 'high' or 'unclear'), across the domains of 'patient selection', 'index test', 'reference standard' and 'flow and timing'. Studies were individually assessed using the QUADAS-2 worksheet (18) by two reviewers (Author 1 and Author 4), and consensus reached by discussion.

Results

A total of 5753 articles were returned through database searches (after removal of duplicates). Titles and abstracts were screened, identifying six potentially relevant articles (19-24). These articles were then reviewed in full text against the inclusion criteria, yielding two articles which were ultimately included in the review (19,24) (Figure 1).

Characteristics of excluded studies

Of the six studies reviewed in full text, the four excluded studies are shown in Table 2. Reasons for exclusion were that the patient's conscious state at the scene was not reported (n=2) (20,23), or that the data did not enable calculation of any measure of diagnostic accuracy (n=2) (21,22).

Table 2. Excluded studies

Study	Country	Reason(s) for exclusion
Clawson et al (2010) (20)	US	Demonstrated a potential association between 'not alert' as determined in a phone call and patient acuity; however did not directly compare field findings of conscious state
Gibson et al (2013) (21)	UK	Discussed communication difficulties around conscious state determination in emergency calls for stroke, did not include sufficient data to determine call-taker assessment of conscious state and thus calculate any measure of diagnostic accuracy
Jones et al (2011) (22)	UK	Did not itself include sufficient data to calculate any measure of diagnostic accuracy (conference abstract reporting on same study as Gibson et al) (21)
Ohshige et al (2009) (23)	Japan	Formulated an algorithm to predict patient acuity based on several factors in a phone call, including conscious state, however did not directly compare field findings of conscious state

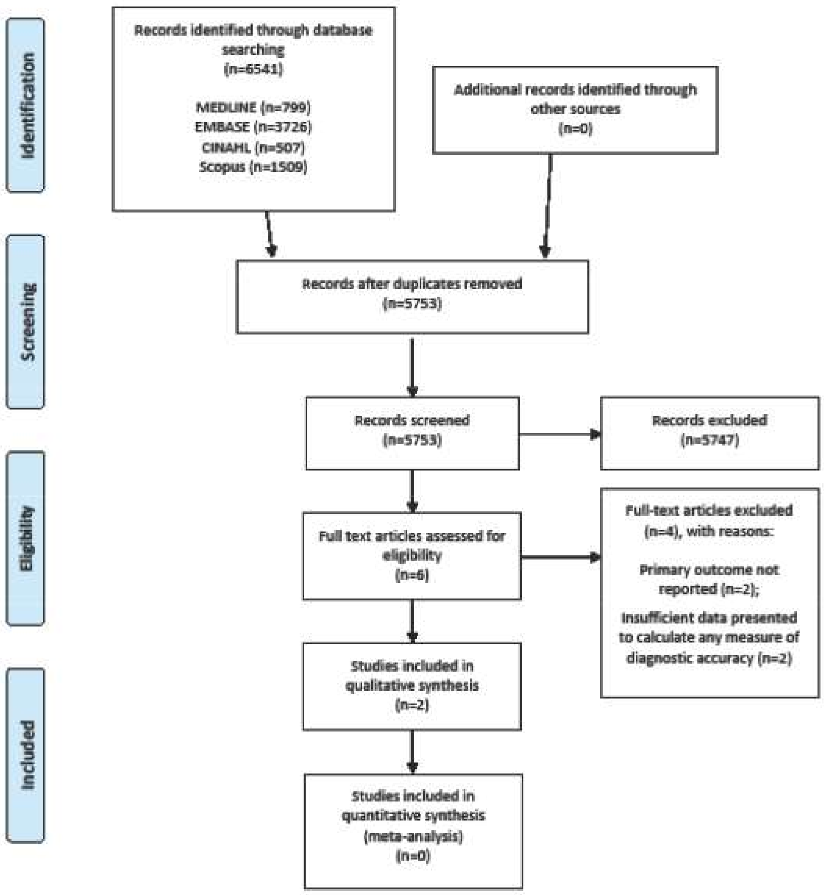

Figure 1. PRISMA flow diagram

Study characteristics

The two included studies (19,24) were retrospective observational studies. Their characteristics are summarised in Table 3. Both studies measured conscious state as determined by the call-taker during the emergency call, along with conscious state as determined by the EMS responder who attended the patient. However, there were notable differences in the objectives of the two studies. Radonic et al (24) sought to describe the characteristics of patients who were reported to be unconscious at the time of the emergency call (ie. allowing calculation of positive predictive value, but not other measures of diagnostic accuracy). In contrast, Bach & Christensen (19) examined all quadrants of the comparison between call-taker and on-scene assessment of conscious state (ie. conscious vs. unconscious as assessed by call-taker, compared to conscious vs. unconscious as determined on-scene), allowing calculation of sensitivity, specificity, positive predictive value and negative predictive value.

Both studies (19,24) measured consciousness as a binary variable (conscious vs. unconscious) and did not examine the spectrum of altered conscious states or reduced levels of consciousness. Bach & Christensen (19) defined 'unconscious' as a Glasgow Coma Scale (GCS) (25) score of less than 9, while the distinction between conscious and unconscious was not defined by Radonic et al (24).

Synthesis of results

Along with the disparate nature of studies already identified, differences in the designs of emergency medical systems also make the studies difficult to compare. Radonic et al (24) studied a hospital-based system where calls were handled by emergency doctors. Bach & Christensen (19) based their study on a system where calls are answered by a police call centre. Due to the disparate nature of studies, and different skills levels of the call-takers, we considered there is too much clinical heterogeneity for meta-analysis.

Results of individual studies

Results for each study, with calculated measures of diagnostic accuracy, are shown in Tables 4a and 4b.

Radonic et al (24) selected 1352 patients who were identified as unconscious in the emergency call. Medical records were missing for 435 patients; thus 917 patient records were reviewed. Of these patients, 602 were found to be unconscious at scene (including 180 deceased patients) and 315 conscious, giving a positive predictive value of 65.6% for call-taker determination of unconsciousness.

Bach & Christensen (19) reviewed 1655 calls for accuracy of call-taker determination of conscious state. Of the 1024 patients classified by call-takers as conscious, 972 were found on-scene to be conscious and 52 unconscious. Of 631 classified by call-takers to be unconscious, 388 were conscious on-scene and 243 unconscious. This gives a sensitivity of 82.4%, specificity of 71.5%, positive predictive value of 38.5% and negative predictive value of 94.9%.

Table 4a. Bach & Christensen (19)

	On-scene: unconscious	On-scene: conscious	Total
Call-taker: Unconscious	243	388	631
Call-taker: Conscious	52	972	1024
Total	295	1360	1655

Diagnostic accuracy of identifying unconscious patients: sensitivity = 82.4% (95% CI: 77.5-86.6%); specificity = 71.5% (95% CI: 69.0-73.9%); positive predictive values (PPV) = 38.5% (95% CI: 36.2-40.9%); negative predictive values (NPV) = 94.9% (95% CI: 93.6-96.0%)

Table 4b. Radonic et al (24)

	On-scene: unconscious	On-scene: conscious	Total
Call-taker: unconscious	602	315	917
Call-taker: conscious	Not reported	Not reported	Not reported
Total	Not reported	Not reported	Not reported

PPV of identifying unconscious patients = 65.6% (95% CI: 62.5-68.7%); sensitivity, specificity and NPV not ascertainable

Table 3. Included studies

Study	Country	Study type	Triage decision support tool	Outcome measure	Call-taker type	On-scene assessor type	# of cases analysed	Data source for call-taker findings	Data source for on-scene findings
Bach & Christensen (2007) (19)	Denmark	Observational, retrospective	Criteria based dispatch (11)	Unconscious (GCS<9)	Police	Doctor	1655	Dispatch data	Patient care records
Radonic et al (1995) (24)	Croatia	Observational, retrospective	Not specified	Unconscious (measure not defined)	Doctor	Doctor	917	Medical records	Medical records

Quality and bias assessment
Results for the assessment of quality and risk of bias (using QUADAS-2) (17) are summarised in Table 5.

The index test (call-taker assessment of conscious state) in Bach & Christensen (19) was based on a triage decision support tool, which we interpreted as providing some degree of consistency in conscious state assessment between calls. The basis for call-taker assessment of conscious state was not specified in Radonic et al (24); therefore it is unclear whether a lack of a systematic approach to call-taker determination of conscious state may have contributed to bias in this study. In relation to the reference test (on-scene assessment of conscious state), Bach & Christensen (19) specified a threshold GCS of less than 9 as defining unconsciousness. We assigned a low risk of bias to this determination, due to its formal definition, and the fact that it was determined by medical experts (in this study, anaesthesiologists). No definition of consciousness was supplied in Radonic et al (24). However, given the binary nature of the on-scene classification (conscious vs. unconscious), and the fact that on-scene assessment of conscious state was made by clinicians, we assigned this study a low risk of bias in the reference standard.

In terms of study flow and timing, both studies had a large number of patients excluded due to missing variables or unlinked data, thereby introducing potential bias. In Bach & Christensen (4), of the study's starting cohort of 2961 emergency calls allocated a Mobile Emergency Care Unit (MECU), only 1655 cases (56%) remained in the final study population. In Radonic et al (24), data were missing for on-scene patient assessment for a large part of the study cohort: 435 of 1352 records (32%). Furthermore, the number of cases missing the index test for this study (ie. before the starting cohort of 1352 cases) is not stated.

For both studies (19,24), there were significant limitations in applicability to the review question. While Radonic et al (24) examined a broad selection of patients (apparently across all medical conditions), their study was restricted to patients assessed by call-takers as being unconscious. Bach & Christensen (19) also examined a broad selection of patients (across all medical conditions), and examined patients assessed by call-takers as both conscious and unconscious. However, their cohort was restricted to those patients assessed by the call-taker as being higher acuity, identified as patients who were allocated MECU at dispatch (MECU physicians are only allocated to higher acuity patients in their system).

Discussion

Reduced conscious state is a key factor in determining patient acuity in systems used internationally for triaging emergency calls. Determining whether the patient is conscious or not is typically one of the first and most important triage questions asked in all emergency calls (along with whether the patient is breathing) (10,11). Furthermore, for patients initially identified as conscious, it is common among dispatch protocols for further questions to be asked to determine if the patient has an altered conscious state (10,11). Despite the importance of determining conscious state, this systematic review identified very little literature providing a quantitative assessment of the accuracy of call-taker assessment of conscious state.

Only one study (Bach & Christensen) (19) provided all measures of diagnostic accuracy of determining conscious state (sensitivity, specificity, PPV and NPV). Bach & Christensen (19) compared call-takers determination of whether the patient was conscious with medical professionals' determination of whether the patient was conscious on arrival at the scene, and found a sensitivity (of determining the patient as unconscious) of 82.4%, specificity of 71.5%, NPV of 94.9% and PPV of 38.5%. This is the only study to date to have reported on the sensitivity, specificity and NPV of determining conscious state during emergency calls, and is therefore significant in providing the only comprehensive evidence that it is common for call-taker assessment of conscious state to differ from what is found by clinicians on-scene. Rephrasing the statistics above in terms of inaccuracies (ie. discordant determinations of conscious state), 17.6% of patients who were unconscious on-scene were classified as conscious during the call (1-sensitivity); 28.5% of patients who were conscious on-scene were classified as unconscious during the call (1-specificity), and 61.5% of patients dispatched as unconscious were found to be conscious on-scene (1-PPV). The only statistic with high accuracy was the NPV, with only 5.1% of patients dispatched as conscious being found to be unconscious on-scene (1-NPV).

One feature of the Bach & Christensen (19) study was a tendency towards false positives (patient determined as

Table 5. QUADAS-2 results

Study	Risk of bias				Applicability concerns		
	Patient selection	Index test	Reference standard	Flow and timing	Patient selection	Index test	Reference standard
Bach & Christensen (2007) (19)	☑	☑	☑	☒	☒	☑	☑
Radonic et al (1995) (24)	☑	?	☑	☒	☒	☑	☑
☑ = Low risk ☒ = High risk ? = Unclear risk							

unconscious in the call, but conscious on-scene), over false negatives (determined as conscious in the call, but unconscious on-scene). This is evident in the sensitivity (of identifying the patient as unconscious) being higher (at 82.4%) than the specificity (71.5%), as well as the NPV (94.9%) being higher than the PPV (38.5%). This tendency is consistent with the generally risk-averse approach of EMS dispatch (1-7). However, while this could be interpreted as evidence of a conservative approach to call-taker determination of unconscious patients, it is also possible that a tendency towards false positives could arise from transitions in patient conscious state in the period between the emergency call and arrival at the scene, ie. if the likelihood of unconscious patients becoming conscious, is higher than conscious patients becoming unconscious. One way to measure the impact of changes in patient conscious state between the emergency call and arrival on-scene, could be to statistically model how the measures of diagnostic accuracy vary as a function of response time. This was outside the scope of the Bach & Christensen study (19) but could be an informative aspect of future research.

The second study in this review (Radonic et al) (24) restricted their study cohort to calls that were initially classified by the call-taker as an unconscious patient, and then examined how the patient's conscious state was classified by clinicians on arrival to the scene. Therefore, the only measure of diagnostic accuracy that could be calculated from this study was PPV, which had a value of 65.6%. This is much higher than the PPV of 38.5% reported by Bach & Christensen (19). Without the full picture of all measures of diagnostic accuracy, there is no indication of whether the higher PPV in the Radonic et al (24) study came at the cost of decreased sensitivity to detect unconscious patients. Furthermore, differences in study design make meaningful comparisons of the PPV between these two studies difficult – in particular, the study cohort for Bach & Christensen (19) was restricted to higher acuity calls (receiving MECU), whereas the study cohort for Radonic et al (24) was not restricted by patient acuity. Regardless of the reasons for the higher PPV in the Radonic et al (24) study, this study is important in further highlighting that it is common for call-taker assessment of conscious state to differ from what is found by clinicians on-scene.

Two additional studies that were excluded from this review remain noteworthy. Gibson et al (21) reported on emergency calls for patients exhibiting stroke symptoms and the communication difficulties experienced. The study was not designed to quantitatively measure accuracy and instead was part of a qualitative project to investigate communication difficulties in the context of acute strokes. While this study did not provide data on the final call-taker determination of patient conscious state, or on-scene determination of conscious state, the qualitative component of this study provides useful insights into the challenges experienced when call-takers attempt to glean information about a patient's conscious state, eg. callers had difficulty determining a conscious level, there was frequent miscommunication and a need to clarify conscious level, and callers conflated conscious level with breathing difficulties.

A study by Clawson et al (20) was excluded because the data were insufficient for a patient's conscious state at the scene to be determined. While cardiac arrest was an outcome variable (for which many patients will be unconscious at the time of the call, or on arrival at the scene), the cohort did not exclude EMS-witnessed arrests - therefore an unknown proportion of patients may have been conscious on EMS arrival at the scene. The focus of Clawson et al (20) was to examine the predictive value, among falls patients, of being classified in the emergency call as unconscious or not alert (vs. alert). While not assessing accuracy of conscious assessment per se, the Clawson et al study (20) is important in demonstrating the utility of call-taker questioning of conscious state. They found that falls patients classified in the emergency call as not alert or unconscious were more than 15 times more likely to have a cardiac arrest than falls patients classified as alert in the call (20).

Conscious state can be considered as a scale, with a patient fully aware, alert and oriented at one end of the spectrum and completely unresponsive at the other. Between these, other descriptors of conscious state can be used such as lethargic, confused, responsive to voice or responsive to pain. Binary descriptors of 'conscious' or 'unconscious' refer to patients with a conscious state above or below a certain point on this scale. The Bach & Christensen and Radonic et al studies (19,24) both measured this binary state of conscious versus unconscious. Bach & Christensen (19) defined 'unconscious' as a patient with a GCS (25) score of 8 or less, which can be approximated to include patients classed as responsive to pain or unresponsive on the AVPU (Alert, Verbal response, Pain response, Unresponsive) scale used for rapid conscious state assessment (26,27).

Patients with an altered conscious state but considered conscious may still have a condition requiring urgent attention, such as hypoglycaemia, head trauma or stroke. This is recognised in hospital emergency department triage systems where conscious patients with an altered conscious state are given a high priority, for example the Australasian Triage Scale (28) or Canadian Triage Acuity Scale (29).

Phone triage systems as used by ambulance services also recognise the potential urgency of altered conscious states where a patient is conscious, and attempt to discern these conscious states. Both the Medical Priority Dispatch System (MPDS) and Criteria Based Dispatch ask callers toward the beginning of the call if the patient is conscious, and further questioning about conscious state will often follow. In MPDS, 28 out of 33 chief complaint protocols ask: "is s/he completely alert (responding appropriately)" (10). Criteria Based Dispatch includes questions about whether the patient is able to respond, follow simple commands and answer questions in 12 out of 26 of its chief complaints where an altered conscious state may be of concern. These questions should discriminate patients who are conscious but not alert (ie. fall in the verbal response category in the AVPU scale).

The two studies (19,24) included in this review may provide some evidence for recognition of unconscious patients, however there were no studies found that demonstrated reliability of this further questioning of altered conscious states in conscious patients. As this is a key part of the phone triage for many emergency calls, it is recommended that research be carried out to determine the reliability of this questioning.

Limitations

This review was limited solely to studies where accuracy of conscious state assessment could be measured. The question of accuracy is an important measure, as improvements in accuracy of conscious state assessment would be expected to lead to improvement of dispatch prioritisation. However, this necessarily meant that studies with other outcome measures of patient acuity which did not include conscious state at scene were excluded from the study. For example, studies investigating accuracy of cardiac arrest recognition in emergency calls were excluded because they did not report on findings of conscious state per se, even though questioning about consciousness may have led to the recognition of cardiac arrest.

Conclusion

There is a scarcity of published research into the accuracy of conscious state determination in emergency calls, with only two studies (19,24) providing quantitative measures. These studies both show it is common for call-taker assessment of conscious state to differ from what is found on-scene. From the only study (19) to include all measures of diagnostic accuracy (sensitivity, specificity, PPV and NPV), there appears to be a tendency toward false positives (patient determined as unconscious in the call, but conscious on-scene), over false negatives (determined as conscious in the call, but unconscious on-scene). Meta-analysis was not undertaken due to significant levels of clinical heterogeneity between studies. No studies examined the accuracy of determining patient conscious state for patients that are intermediate on the spectrum between fully alert and unconscious. Further research in this area is suggested.

Acknowledgements

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Conflict of interest

Jason Belcher and Austin Whiteside are employed full time by St John Western Australia (SJWA) as Ambulance Paramedic and Operations Manager respectively. Judith Finn receives partial salary support from SJWA, and both Judith Finn and Stephen Ball have adjunct appointments with SJWA.

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4.4. Results of updated literature review since initial search

The initial literature search for this review and published manuscript was conducted in August 2018. A further literature search was performed on 18 July 2022 to find any further literature since the initial review. The same methodology as the original review was applied.

A final total of 1,448 articles (after removal of duplicates) was found through searching of the four databases for literature indexed in August 2018 or later. Titles and abstracts were screened identifying four potentially relevant articles:

1. Mohindru J, Griggs JE, de Coverly R, et al. Dispatch of a helicopter emergency medicine service to patients with a sudden, unexplained loss of consciousness of medical origin. *BMC Emerg Med*. 2020;20(1):92. doi:10.1186/s12873-020-00388-x[44]
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4. Crabb DB, Elmelige YO, Gibson ZC, et al. Unrecognized cardiac arrests: A one-year review of audio from emergency medical dispatch calls. *The American Journal of Emergency Medicine*. 2022;54:127-130. doi:10.1016/j.ajem.2022.01.068[46]

The articles were then reviewed in full text against the inclusion criteria, yielding two articles that could be included in the further review.

4.4.1. Articles identified

The characteristics of the studies reviewed in full-text are shown at Table 6:

Table 6: Studies reviewed in full-text from updated literature search

Study	Description	Met inclusion criteria Yes/No	Reason for exclusion (if not included)

Mohindru et al (2020)[44]	Observational study detailing characteristics of patients with a loss of consciousness with unknown medical cause for whom a helicopter EMS service was dispatched	Yes	
Samdal et al (2021)[45]	Observational study comparing dispatch decision for physician-staffed helicopter response versus ground based EMS, to patient acuity.	No	While altered conscious state was one of many dispatch criteria, did not directly report conscious state on telephone or scene assessment.
Belcher et al (2021)[38]	Observational study comparing assessment of conscious state (in patients identified as conscious) in emergency call versus on-scene findings.	Yes	
Crabb et al (2022)[46]	Observational study of Out of Hospital Cardiac Arrest (OHCA) patients who were not recognised to be in cardiac arrest on the emergency call	No	While all patients were recognised as unconscious on the emergency call, it is not clear from the methodology if all were found in cardiac arrest on arrival of EMS, or if EMS-witnessed arrests were included, and thus whether it can be assumed that patients were unconscious on EMS arrival.

The included study from Mohindru et al (2020)[44] details 127 patients, however only 29 of these were relevant for this review as they had a helicopter dispatch based on the information (including conscious state) in the emergency call. The remainder were requests for helicopter taskings from clinicians involved in the case, most commonly already at the scene. Patients were included if they had a loss of consciousness from medical cause not due to cardiac arrest or seizure. Patients were reported as unconscious at the time of the call and had characteristics recorded on arrival of the helicopter response, which included their GCS. The study stratifies patients into three bands of GCS – one of these is GCS 3-8 which aligns with the range for unconscious patients as per Bach & Christensen's study(47) (GCS<9).

The other study that met inclusion criteria – Belcher et al (2021)(38) – was one of my own, produced as part of this thesis and discussed in Chapter 5. This study compared dispatcher determination of altered conscious states in conscious patients, against patient conscious state recorded on arrival of paramedics. Rather than describing a specific subset of emergency calls as seen in other studies, this was a system-wide analysis.

4.4.2. Study characteristics, synthesis of results and meta-analysis

The included studies and their characteristics from both the original systematic review and the updated search are shown at Table 7, and the summarised results from each study shown at Table 8.

Table 7: Characteristics of included studies

Study	Country	Study type	Inclusion criteria	Triage Decision Support Tool	Outcome measure	Call-taker type	On-scene assessor type	Number of cases analysed	Data source for call-taker findings	Data source for on-scene findings
Bach & Christensen (2007)[47]	Denmark	Observational retrospective	Patients for whom specialist high acuity response resource was dispatched	Criteria Based Dispatch [13]	Unconscious (GCS<9)	Police	Doctor	1655	Dispatch data	Patient care records
Radonic et al. (1995)[48]	Croatia	Observational retrospective	Unconscious patients identified on call	Not specified	Unconscious (measure not defined)	Doctor	Doctor	917	Medical records	Medical records
Mohindru et al (2020)[44]	UK	Observational retrospective	Unconscious patients on call meeting helicopter dispatch criteria, with loss of consciousness not related to trauma, arrest, seizure.	NHS Pathways [49]	Unconscious (GCS 3-8)	EMD	Paramedic and doctor	29	Dispatch data	Medical records
Belcher et al (2021)[38]	Australia	Observational retrospective	Patients identified as conscious on emergency call	MPDS[12]	V/P/U on AVPU	EMD	Paramedic	109,678	Dispatch data	Patient care records

Table 8: Results and measures of diagnostic accuracy for included studies.

Study	True Positives	False Positives	False Negatives	True Negatives	Sensitivity	Specificity	PPV	NPV
Bach & Christensen (2007)[47]	243	388	52	972	82.4%	71.5%	38.5%	94.9%
Radonic et al. (1995)[48]	602	315	NR	NR	NA	NA	65.6%	NA
Mohindru et al (2020)[44]	13	26	NR	NR	NA	NA	44.8%	NA
Belcher et al (2021)[38]	1282	18,077	551	89,768	69.9%	83.2%	6.62%	99.4%
NR: Not reported. NA: Not ascertainable.								

In the initial systematic review, no quantitative meta-analysis was performed between the two included studies as there was too much clinical heterogeneity between them based on the initial assessor. These two studies were based on identifying unconscious patients in the emergency call.

Of the two new studies identified (Mohindru et al[44] and Belcher et al[38]), neither are homogenous enough with any other included study – Mohindru et al has inclusion criteria that are not generalisable, and Belcher et al considers conscious patients and identification of altered conscious states, as opposed to unconscious patients as per the other studies. The heterogeneity between all the included studies means it remains impossible to perform any meaningful quantitative meta-analysis.

4.5. Summary

Published literature regarding the association between conscious state assessment in an emergency telephone call, and findings of the patient's conscious state at the scene on arrival of first responders, was assessed and synthesised in this review. Two articles were found in the original published systematic review, both dealing with identification of unconscious patients. A third was found on the updated literature search dealing with detection of altered conscious states in patients identified as conscious on the emergency call. This third paper is my own which had been produced as part of this thesis subsequent to the initial systematic review being performed. No quantitative meta-analysis was performed due to the clinical heterogeneity.

Despite the key role that conscious state assessment has in internationally used emergency dispatch triage systems[12], there is a surprising lack of published research assessing the accuracy of this questioning. Furthermore, to my knowledge, my cohort study[38] (identified in my updated systematic review) is the only system-wide study (as opposed to addressing a specific subset of calls) and the only study on the accuracy of call-taker determination of altered conscious state among patients who are initially identified as conscious.

Although no quantitative meta-analysis was performed, individually the studies showed conscious state assessed in an emergency call differed from findings on scene frequently. For the most part this was in the form of high numbers of false positives (which may generate over-triage), however my study[38] on altered conscious states in conscious patients also demonstrated a concerning rate of false negatives (under-triage) which indicates this is not simply a system geared towards risk aversion.

Further research is recommended into the accuracy of conscious state assessment in emergency calls, and methods to improve it.

Chapter 5. Analysis of the accuracy of EMD-determined conscious state

5.1. Overview

In this chapter, the findings of the first analytical study included in this thesis are presented. The study analyses the association between a patient's conscious state as reported on an emergency telephone call, and their conscious state as reported by paramedics on arrival on scene. It addresses the knowledge gap from the published systematic review in Chapter 4 which found very limited literature addressing accuracy of determination of a patient's conscious state in an emergency call, and none focussing on altered conscious states in conscious patients.

This study is a population-based analysis of a year of emergency calls. The full methodology is described in Chapter 3 and the published manuscript.

My findings are reported in the following manuscript that was published in the Australasian Journal of Paramedicine in 2021:
Belcher J, Finn J, Whiteside A, Ball S. 'Is the patient completely alert?' – accuracy of emergency medical dispatcher determination of patient conscious state. *Australasian Journal of Paramedicine*. 2021;18:1-10. doi:10.33151/ajp.18.858[38]

The published manuscript includes reproduced following the methodology. As the Australasian Journal of Paramedicine is an open-access journal, no permission was required for its reproduction.

5.2. Detailed Methodology

The published manuscript includes the methodology for the study and is reproduced after this section. This section provides further detail on some key features of the methodology including rationale for some choices in the study design.

5.2.1. Study design

The study was a retrospective observational study of the association between Emergency Medical Dispatcher (EMD) determined patient conscious state (alertness, as per the question asked in MPDS), and conscious state findings by paramedics on arrival at scene. The dataset comprised all emergency calls in the Perth metropolitan area for whom an emergency ambulance call was made in a 1-year period, 27 November 2017 to 26 November 2018.

While the term "accuracy" is used for this first level of prediction in the overall concept of the thesis, it is recognised that it is not possible to know what the patient's actual conscious state was at the time of the call - as the patient may improve or deteriorate in between the call and the arrival of paramedics. I also recognise the term "accuracy" is usually used to refer to the precision of a measurement Thus, it is recognised that rather than accuracy per se, the question that is being asked is that of the predictive value for what the findings on arrival of paramedics will be.

5.2.2. Data sources and determination of conscious state

EMD and paramedic findings for comparison were sourced from SJWA data sets as follows:

5.2.2.1. EMD conscious state findings

EMD findings were sourced from the SJWA Computer Aided Dispatch (CAD) system. When an EMD takes a call using the ProQA software, the details including the MPDS determinant code are saved to the call record in the CAD system. I used this determinant code to directly infer the conscious state that was recorded by the call-taker.

In 27 of the 32 MPDS protocols, the question is asked of the caller "is s/he [the patient] completely alert?". The five protocols that do not ask this question are Cardiac or respiratory arrest/death, Convulsions/Fitting, Inaccessible incident/Other entrapments, Pregnancy/Childbirth/Miscarriage and Unknown problem (Table 9). Unfortunately, the ProQA software does not allow the answers to individual questions to be exported across multiple records for analysis. Thus, the answer to this question cannot be directly determined without manually opening each individual case – something that is not reasonably practical with over 100,000 calls in the data set for analysis. However, in most cases the answer to this question can be determined by the MPDS determinant code – where this question exists, the protocol has a "Not Alert" determinant which can be used to make this determination.

Table 9: MPDS Protocols that do not include a "Not Alert" determinant[12]

09 Cardiac or respiratory arrest/death
12 Convulsions/Fitting
22 Inaccessible incident/Other entrapments (non-vehicle)
24 Pregnancy/Childbirth/Miscarriage
32 Unknown problem

EMD classification of the patient as Alert or Not Alert was thus determined as follows:

- Where the Not Alert determinant was selected, the patient was considered **Not Alert** for EMD determination.
- Where the selected determinant was ranked *below* the Not Alert determinant, the patient was considered **Alert** from a EMD perspective (as ProQA would have selected the higher-ranked Not Alert determinant if the patient had been indicated to not be alert).
- Where the selected determinant was ranked *above* the Not Alert determinant, the patient's conscious state was considered ambiguous from an EMD perspective.

This determination is based on the inherent hierarchy of determinants within an MPDS protocol[34]. While this method meant some cases were excluded because their EMD determined conscious state was ambiguous, the fact that MPDS always places the "Not Alert" determinants in at the DELTA level, and usually high within this section, meant that the number of determinants excluded was low. Furthermore, the nature of the excluded protocols was such that they obviously describe patients likely to be extremely high acuity (for example, "ineffective breathing", "person on fire") and requiring a high priority response, so the conscious state is not clinically meaningful for differentiating dispatch priority. The determinants that were excluded for being above the Not Alert determinant are shown in Table 10.

Table 10: MPDS determinants excluded as they are ranked above the "Not Alert" determinant[12]

02-E-01 Allergies (Reactions)/Envenomations (Stings, Bites) > Ineffective Breathing
06-E-01 Breathing Problems > Ineffective Breathing
07-E-01 Burns > Person on Fire
11-E-01 Choking > Complete Obstruction/Ineffective Breathing
11-D-01 Choking > Abnormal Breathing (Partial Obstruction)
14-E-02 Drowning (near)/Diving/SCUBA accident > Underwater (domestic rescue)
14-D-02 Drowning (near)/Diving/SCUBA accident > Underwater (specialised rescue)
14-D-03 Drowning (near)/Diving/SCUBA accident > Stranded (specialised rescue)
14-D-04 Drowning (near)/Diving/SCUBA accident > Just resuscitated and/or defibrillated
15-E-01 Electrocution/Lightning > Not breathing/Ineffective breathing
15-D-03 Electrocution/Lightning > Not disconnected from power
15-D-04 Electrocution/Lightning > Power not off or hazard present
15-D-05 Electrocution/Lightning > Extreme Fall (=>10m/30ft)
15-D-06 Electrocution/Lightning > Long Fall
17-D-01 Falls > Extreme Fall (=>10m/30ft)
23-D-02 Overdose/Poisoning (ingestion) > Changing colour
29-D-01 Traffic/Transportation Incidents > Major incident
29-D-02 Traffic/Transportation Incidents > High mechanism
29-D-03 Traffic/Transportation Incidents > High velocity impact
29-D-04 Traffic/Transportation Incidents > HAZMAT
29-D-05 Traffic/Transportation Incidents > Trapped victim
31-E-01 Unconscious/Fainting (Near) > Ineffective breathing

While it is not possible to know whether a patient's condition on the telephone call changed between the call and arrival of paramedics, callers are instructed in the MPDS scripting "if anything changes or he/she gets worse in anyway, call us back immediately for further instructions". If a call-back is received from a scene the call will be re-triaged using MPDS and the CAD system updated with the new code. Thus, the MPDS code used for comparison is always the one selected from the most recent triage.

5.2.2.2. Paramedic conscious state findings

Paramedic-assessed conscious state on arrival to the patient was extracted from the SJWA Electronic Patient Care Record (ePCR) system. As detailed in the Background chapter, paramedics enter an initial conscious state on arrival at the patient into their ePCR in a six-level descriptive scale consisting of Alert, Confused, Drowsy, Voice Response, Pain Response and Unresponsive. I used this entry to represent paramedics' findings, for comparison with dispatch coding of patient conscious state.

While these descriptions may be considered subjective as compared to a GCS, I chose to use this for several reasons:

- GCS is recorded in a formal set of observations, which may be some time after paramedics' initial arrival to the patient. This could potentially occur after initial interventions if immediate management was required based on the paramedics' primary survey findings, which may affect the patient's conscious state.
- It is difficult to determine an exact GCS threshold that aligns with the description of "not alert" given the range of scores that the descriptors can align to.
- Although GCS is a systematic scoring system and should in theory be less subjective, it is well established that there are problems with inter-rater reliability, particularly in the prehospital field(50-53) so may not have any advantage over the descriptive scale in this regard.

While SJWA paramedics record initial conscious state based on a six-level scale (Alert, Confused, Drowsy, Voice response, Pain response, Unresponsive), for the primary analysis in this chapter, I collapsed this down to the four-level AVPU scale. This conversion was made so that the categorisation of patient conscious state for this chapter would use an internationally-recognised scale for rapid conscious state triage in emergency medical settings(17, 54, 55). Specifically, I combined the categories of Alert, Confused and Drowsy into to the single AVPU category of Alert. This treatment of the data is also consistent with the interpretation by St John WA clinicians for on-scene decision-making, that patients categorised as Confused or Drowsy would be considered Alert on the AVPU scale, due to their conscious state being above (i.e., less altered than) the AVPU Voice Response category (pers. comm. Deane Coxall, Clinical Quality Manager, SJWA, March 2020). Thus, ultimately for the primary analysis, patients who were recorded as Alert, Confused or Drowsy were treated as being **Alert**, and those recorded as Voice Response, Pain Response or Unresponsive were treated as **Not Alert**.

Although using the AVPU scale is more generalisable for any future comparisons between services given the widespread use of this scale, the addition of the Confused and Drowsy descriptors in SJWA patient care records allows higher fidelity understanding of a patient's level of consciousness than AVPU. This gave me the opportunity to conduct a secondary analysis as a sensitivity analysis using an alternative definition. I performed this analysis treating *any* altered conscious state as Not Alert - in this analysis, Confused and Drowsy were instead treated as Not Alert.

Performing a primary and secondary analysis in this way also addresses the two possible interpretations of "Not Alert" within MPDS identified in the Background chapter (see section 2.4.5). The primary analysis aligns to the interpretation of MPDS protocol 26 where the descriptors "confused" and "lethargic" do not meet the threshold to be considered "Not Alert", while the secondary is aligned with the face value of the wording of the question in MPDS– "is [the patient] *completely alert*?".

5.2.3. Inclusion and exclusion criteria

Calls were included for analysis where:

1. The call was within the 12-month period of 27 November 2017 to 26 November 2018. This was, at the time of conducting the study, the most recent 12-month period where there had been no version change in MPDS as used by SJWA thus there was a consistent set of determinant codes.
2. The call was an emergency call that used MPDS (as opposed to an interhospital transfer or other tasking that was not a call for help in the community).
3. The call was within the Perth metropolitan area. I restricted the cohort to the metropolitan area rather than the entire state for two reasons. Firstly, ambulance cases in the metropolitan area are attended by registered paramedics, so there is a defined standard of education meaning there should be consistency in conscious state assessment, as opposed to regional areas that may have a variance in training with volunteer ambulance officers. Secondly, the unique geography of regional Western Australia with its remoteness may not be a generalisable environment when considering ambulance response times, whereas the metropolitan area should be reasonably generalisable to other metropolitan cities around the world.

Calls were excluded where:

1. The patient was identified on the call as being unconscious or in cardiac arrest. In this study I focussed specifically on the question of the patient's alertness, i.e., looking for altered conscious states in patients identified as conscious;
2. The call was triaged on one of the five MPDS protocols that does not include the question around the patient's alertness (Table 9);
3. The call was cancelled prior to paramedics' arrival;
4. No patient contact was made by the paramedics (e.g., where the patient could not be located);
5. There were multiple patients involved in the incident. It would not be possible to automatically determine which patient, if any, the telephone triage of conscious state was conducted on;
6. The patient's initial conscious state was not recorded by paramedics on their ePCR;
7. The call was one of the MPDS codes excluded as it the answer the alertness question was ambiguous (Table 10).

Exclusions were processed in the above order and a flow diagram produced showing the number of calls excluded at each level. This order was chosen as the final two items are those with potential to introduce bias, so the number of calls excluded on these can be easily quantified for quality and bias assessment in any future literature review or meta-analysis.

5.2.4. Primary analysis

Data from CAD and ePCR were linked by an individual case number for each call. For each included case, the EMD-determined conscious state (Alert or Not Alert) was determined from the MPDS code, and the paramedic-determined conscious state (Alert or Not Alert) was determined from the on-arrival conscious state as recorded in their ePCR, as detailed above.

Measures of diagnostic accuracy were calculated, with a patient having an altered conscious state (i.e. being Not Alert) considered the positive condition. Paramedic assessment was considered the "gold standard" actual condition, with EMD assessment being considered the predicted condition.

In this context, the following definitions were made:

- **True positive** where both the EMD and paramedics determined the patient to be Not Alert
- **True negative** where both determined the patient to be Alert
- **False positive** where the EMD determined the patient to be Not Alert but paramedics determined them to be Alert
- **False negative** where the EMD determined the patient to be Alert but paramedics determined them to be Not Alert.

As described in the methodological overview in Chapter 3, I used these definitions to calculate the following measures of diagnostic accuracy:

- **Sensitivity:** proportion of paramedic determined Not Alert patients also determined as Not Alert by EMD
- **Specificity:** proportion of paramedic determined Alert patients also determined as Alert by EMD
- **Positive Predictive Value (PPV):** proportion of EMD-determined Not Alert patients also determined as Not Alert by paramedics
- **Negative Predictive Value (NPV):** proportion of EMD-determined Alert patients also determined as Alert by paramedics

These are demonstrated in the matrix shown in Figure 5 (Chapter 3). The overall results were also shown on a matrix of this nature.

Results were reported overall for the whole data set. I also stratified calls by MPDS protocol and reported this above analysis for each protocol to understand whether there were differences in accuracy between different types of patients. I performed a χ^2 analysis to test for significance in differences between positive and negative predictive values as detailed in the manuscript[(38)].

5.2.5. Secondary sensitivity analysis based on alternative definition

As detailed above, I repeated the analysis with an alternative definition of Not Alert to include *any* altered conscious state. In this definition, the paramedic assessment was redefined to classify any patient with a presenting conscious state of Confused or Drowsy, in addition to Voice Response, Pain Response or Unresponsive in the analysis above, as Not Alert. The same methodology for analysis was followed.

For the purposes of $\chi 2$ analysis for comparison of results between protocols, the same MPDS protocols that were excluded from the primary analysis due to small denominators were also excluded from this secondary analysis for comparability.

The published manuscript only contains the overall measures of diagnostic accuracy for the whole dataset with this definition, however the full results are reported in this chapter after the manuscript.

5.3. Manuscript

Australasian Journal of Paramedicine

Research

'Is the patient completely alert?' – accuracy of emergency medical dispatcher determination of patient conscious state

Jason Belcher BSc is a MPhil candidate[1] and paramedic[2]; Judith Finn PhD, MEdSt, GradDipPH, BSc is Director[1] and Adjunct Research Professor[2]; Austin Whiteside PGCert(EMS), AdvDipHSc(PrehospCare) is Operations Manager and paramedic[2]; Stephen Ball BSc, PhD is Research Fellow[1] and Adjunct Senior Research Fellow[2]

Affiliations:
[1]Prehospital, Resuscitation and Emergency Care Research Unit, Curtin University, Perth, Western Australia
[2]St John Ambulance, Western Australia

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Abstract

Introduction
During emergency ambulance calls, one of the key issues assessed is the patient's level of consciousness. An altered conscious state can be indicative of a need for a high priority response; however, the reliability of the resulting triage depends on how accurately alertness can be ascertained over the phone. This study investigated the accuracy of emergency medical dispatcher (EMD) determination of conscious state in emergency ambulance calls in Perth, Western Australia.

Methods
The study compared EMD determination of patient alertness based on the Medical Priority Dispatch System (MPDS), with conscious state as recorded by paramedics on arrival, for all emergency ambulance calls in a 1-year period in metropolitan Perth. Diagnostic accuracy was reported across the whole system and stratified by MPDS chief complaint.

Results
There were 109,678 calls included for analysis. In terms of identifying patients as not alert, the overall positive predictive value was 6.62% and negative predictive value was 99.93%, with 10 times as many patients dispatched as not alert than found to be not alert at scene. Sensitivity was only 69.94%. There was significant variation in accuracy between chief complaints.

Conclusion
The study found high levels of inaccuracy between dispatch identification of not-alert patients, and what paramedics found on scene. While not-alert dispatch was 10 times more common than patients being determined not-alert on scene, only 70% of not-alert patients on scene were classified as such during dispatch. Further research is suggested into the factors that affect the accuracy of EMD determination of patient conscious state.

Keywords:
emergency medical services; pre-hospital care; emergency dispatch; triage; conscious state; accuracy

Corresponding Author: Jason Belcher, jason.belcher@postgrad.curtin.edu.au

Introduction

In an emergency ambulance call, a key role of the emergency medical dispatcher (EMD) is to determine the nature and urgency of the medical or traumatic problem. Inaccuracies in this process can lead to under-triage, whereby the patient receives a lower priority response than necessary, with increased risk to the individual patient; as well as over-triage, whereby the patient receives a higher priority response than necessary, with a system-wide risk that resources become unavailable for patients who truly need a high priority response (1-4). Studies have shown widespread inaccuracies in initial telephone triage of patient acuity (5-11).

A key area of questioning in emergency ambulance calls is around patient conscious state – in terms of whether patients are conscious or unconscious, and altered conscious states among conscious patients. Among conscious patients, a sudden altered conscious state can be symptomatic of a high acuity condition such as stroke (12), head trauma (13), hypoglycaemia (14) or poisoning (15). Altered conscious states are recognised as a triage criterion in, for example, the Australasian Triage Scale (16) and international advanced trauma life support protocols (13). In the Medical Priority Dispatch System (MPDS) widely used in ambulance services around Australia and internationally for triage of ambulance calls, determination of patient alertness is used as a basis of dispatch prioritisation for 27 of the 32 chief complaints (17). However, the value of assessing patient conscious state during emergency calls depends on how accurately it can be determined. A recent systematic review (18) found only two studies (19,20) on the accuracy of call-taker determination of consciousness, and no studies on the accuracy of determining reduced conscious states among conscious patients.

To address this knowledge gap, this study sought to investigate the accuracy of EMD determination of reduced conscious state among conscious patients. This study took a system-wide approach to analysing the association between EMD determination of patient alertness and patient alertness recorded by paramedics on arrival at the scene. The primary aim was to estimate the overall accuracy of EMD determination of patient alertness, among patients initially identified as conscious. In addition, this study compared the accuracy of alertness determination between different patient medical conditions (MPDS chief complaints), with a view to target chief complaints for further research.

Methods

Setting

This was a population-based retrospective observational study of the association between EMD determination of patient alertness (using the MPDS) versus findings by paramedics at the scene, stratified by chief complaint. The setting was metropolitan Perth in Western Australia, population 2.06 million in 2018 (21), where St John Western Australia (SJWA) is the sole provider of emergency ambulance services and is staffed entirely by career paramedic crews (22). All emergency (000) ambulance calls in Western Australia are answered by SJWA's State Operations Centre and triaged using the MPDS, before being dispatched to an ambulance crew. SJWA employ layperson EMDs who are trained in the use of the MPDS and are assessed against a MPDS quality assurance program to ensure standards are maintained. There is a significant range of experience among the EMDs represented in this study, from those at the beginning of their career through to those with decades of service (with MPDS being used at SJWA since 2011).

The study ran for the 12 months from 27 November 2017 to 26 November 2018, during which MPDS v13 (17) was in use.

Table 1. The chief complaints used by the Medical Priority Dispatch System v13 (17)

01 Abdominal pain/problems
02 Allergies (reactions)/envenomations (stings, bites)
03 Animal bites/attacks
04 Assault/sexual assault
05 Back pain (non-traumatic/non-recent trauma)
06 Breathing problems
07 Burns (scalds)/explosion (blast)
08 Carbon monoxide/inhalation/HAZMAT/CBRN
09 Cardiac or respiratory arrest/death
10 Chest pain (non-traumatic)
11 Choking
12 Convulsions/fitting
13 Diabetic problems
14 Drowning (near)/diving/SCUBA accident
15 Electrocution/lightning
16 Eye problems/injuries
17 Falls
18 Headache
19 Heart problems/AICD
20 Heat/cold exposure
21 Haemorrhage/lacerations
22 Inaccessible incident/other entrapments (non-vehicle)
23 Overdose/poisoning (ingestion)
24 Pregnancy/childbirth/miscarriage
25 Psychiatric/abnormal behaviour/suicide attempt
26 Sick person (specific diagnosis)
27 Stab/gunshot/penetrating trauma
28 Stroke (cerebrovascular accident)
29 Traffic/transportation incidents
30 Traumatic injuries (specific)
31 Unconscious/fainting (near)
32 Unknown problem

Determination of alertness

For dispatch determination of alertness, the MPDS determinant code for each incident was used, as assigned by the EMD. Using the MPDS, an EMD allocates an emergency call to one of 32 chief complaints (Table 1) based on a caller's initial description of the problem. The EMD then uses a series of scripted questions related to that complaint to assign the relevant determinant code. There is a total of 525 determinant codes across the 32 MPDS chief complaints v13 (17).

Of the 32 MPDS chief complaints, 27 include a question about the patient's alertness: 'is s/he completely alert?' (17) (Table 2a), with a corresponding 'not alert' determinant code selected if the answer is negative (unless a higher severity determinant is relevant). A restriction of ProQA-Paramount (Priority Dispatch Corporation, Salt Lake City, Utah USA), the software used by SJWA to implement the MPDS, is that answers to individual questions cannot be automatically exported across multiple records. Alertness can be deduced, however, for the vast majority of MPDS determinant codes. This is because, in 27 chief complaints, the MPDS has a determinant code that is specific to 'not alert' patients. If a lower ranked code was selected, this indicates that the patient was recorded by the EMD as 'alert'. However, for determinants ranked higher than 'not alert', the answer to the alertness question remains ambiguous, and these cases were excluded from analysis (Table 2b).

Table 2a. Excluded chief complaint protocols that do not contain a 'not alert' determinant

09 Cardiac or respiratory arrest/death
12 Convulsions/fitting
22 Inaccessible incident/other entrapments (non-vehicle)
24 Pregnancy/childbirth/miscarriage
32 Unknown problem

Table 2b. Excluded determinant codes due to ambiguity in alertness. Within each chief complaint, these codes are positioned above (ie. considered to have higher acuity than) the 'not alert' determinant code

02E01 Allergies (reactions)/envenomations (stings, bites) > ineffective breathing
06E01 Breathing problems > ineffective breathing
07E01 Burns > person on fire
11E01 Choking > complete obstruction/ineffective breathing
11D01 Choking > abnormal breathing (partial obstruction)
14E02 Drowning (near)/diving/SCUBA accident > underwater (domestic rescue)
14D02 Drowning (near)/diving/SCUBA accident > underwater (specialised rescue)
14D03 Drowning (near)/diving/SCUBA accident > stranded (specialised rescue)
14D04 Drowning (near)/diving/SCUBA accident > just resuscitated and/or defibrillated (external)
15E01 Electrocution/lightning > not breathing/Ineffective breathing
15D03 Electrocution/lightning > not disconnected from power
15D04 Electrocution/lightning > power not off or hazard present
15D05 Electrocution/lightning > extreme fall (=>10 m/30 ft)
15D06 Electrocution/lightning > long fall
17D01 Falls > extreme fall (=>10 m/30 ft)
23D02 Overdose/poisoning (ingestion) > changing colour
29D01 Traffic/transportation incidents > major incident
29D02 Traffic/transportation incidents > high mechanism
29D03 Traffic/transportation incidents > high velocity impact
29D04 Traffic/transportation incidents > HAZMAT
29D05 Traffic/transportation incidents > trapped victim
31E01 Unconscious/fainting (near) > ineffective breathing

For on-scene determination of alertness, the AVPU assessment as recorded by paramedics on arrival at the scene was used. The four-level AVPU scale (Alert, Voice Response, Pain Response, Unresponsive) (15,23,24) is internationally recognised as a basis for rapid initial conscious state assessments in emergency patients. The levels of the AVPU scale are:

- Alert – patient is awake, can respond to normal voice, can make purposeful movements in response to command or stimulus, can converse
- Responds to voice – patient makes some kind of response (verbal, movement, eye opening) in response to a verbal stimulus (but is not alert)
- Responds to pain – patient makes some kind of response (verbal, movement, eye opening) to a painful stimulus (but not to any level above)
- Unresponsive – patient does not make any response to any stimulus.

SJWA paramedics complete an electronic patient care record for every patient they attend, which is linked to dispatch data by a unique case number.

Patients included

Cases were included for analysis if they were an emergency ambulance call for help in the community (ie. excluding interfacility transfers). Calls were excluded where: the call was dispatched as an unconscious patient, or cardiac or respiratory arrest; the MPDS chief complaint had no 'not alert' determinant (Table 2a); there was no patient contact (eg. call cancelled before patient contact, no patient found); there were multiple patients; conscious state was not recorded by paramedics; and the alertness on the MPDS code was ambiguous (Table 2b).

Analysis

The association between EMD determination and paramedic determination of conscious state (Figure 1) was measured using the following measures of diagnostic accuracy:

- sensitivity (proportion of paramedic-determined not-alert patients also determined as not-alert by EMD)
- specificity (proportion of paramedic-determined alert patients also determined as alert by EMD)
- positive predictive value (PPV) (proportion of EMD-determined not-alert patients also determined as not-alert by paramedics)
- negative predictive value (NPV) (proportion of EMD-determined alert patients also determined as alert by paramedics).

A true positive (for being not alert) was defined as where both the EMD and paramedics determined the patient to be not alert; a true negative where both determined the patient to be alert; a false positive if the EMD determined the patient to be not alert but paramedics determined them to be alert; and a false negative if the EMD determined the patient to be alert but paramedics determined them to be not alert.

These measures were calculated for the whole dataset, as well as stratified by chief complaints; 95% confidence intervals were calculated for these measures of diagnostic accuracy using Clopper-Pearson exact confidence intervals (25). Chief complaints were identified with the highest level of under-recognition of being not alert (false negatives – see Figure 1) along with the highest level of over-identification of being not alert (false positives). This study focussed on positive and negative predictive values in relation to over-triage and under-triage respectively, on the basis that these measurements show how reliably EMD triage questions predict on-scene paramedic findings. To compare chief complaints by positive and negative predictive value, the χ^2 test for heterogeneity was used, with a significance level of $p = 0.05$. Derived from this calculation, the row sum was used for each chief complaint as an indicator of the magnitude of that chief complaint's divergence from the mean – whereby a higher χ^2 row sum indicates greater deviation from the average value (PPV or NPV).

The data were imported into MySQL Community Edition version 8.0 (Oracle Corporation, Redwood Shores, California USA) to prepare summary data (Tables 3 and 4) and further analysed to produce measures of diagnostic accuracy and χ^2 tests (Tables 3 and 5) using Microsoft Excel for Macintosh version 16 (Microsoft Corporation, Redmond, Washington USA).

To meet the requirements of χ^2 analysis, any row with an expected value less than 1 was removed (26). It had been intended to remove rows with expected values less than 5 until less than 20% of cells had expected values below 5 (26), however there were no such rows after removing rows with expected values less than 1.

Sensitivity analysis

In addition to our primary analysis where paramedic-determined alertness was based on the AVPU scale, we undertook a sensitivity analysis with a more restrictive definition of paramedic-determined alert patients. As an extension of the AVPU scale, SJWA paramedics further classify patients who are alert on the AVPU scale into three sub-categories: alert, drowsy or confused. SJWA has placed the descriptors of 'drowsy' and 'confused' hierarchically above 'voice response'. Patients meeting these descriptions as used by SJWA are still able to converse during patient assessment and therefore would meet the definition of 'alert' on the AVPU scale. In our sensitivity analysis, we re-analysed the overall association between dispatch-determined alertness and paramedic-determined alertness, where on-scene alert patients were defined specifically as the subset of AVPU alert patients who were neither confused nor drowsy.

This sensitivity analysis recognises that patient conscious state lies along a spectrum, along with the fact that 'not alert' is not, to our knowledge, formally defined within the MPDS; and allows for the possibility that a dispatch interpretation of alertness is more closely aligned with categorising drowsy or confused patients as not alert.

Ethics

Approval for the study was granted by the Curtin University Human Research Ethics Committee as a sub-study of the Western Australian Pre-hospital Care Record Linkage Project (HR128/2013-46); and by the SJWA Research Governance Committee.

		Paramedic assessment on arrival		
		Not alert	Alert	
EMD assessment	Not alert	True positive (TP)	False positive (FP)	PPV = TP/(TP + FP) % of patients dispatched not-alert who were not-alert on scene
	Alert	False negative (FN)	True negative (TN)	NPV = FN/(FN + TN) % of patients dispatched as alert who were alert on scene
		Sensitivity = TP/(TP + FN) % of not alert patients on scene who were dispatched not alert	Specificity = TN/(FP + TN) % of alert patients on scene who were dispatched as alert	

Figure 1. Measures of diagnostic accuracy used in this study

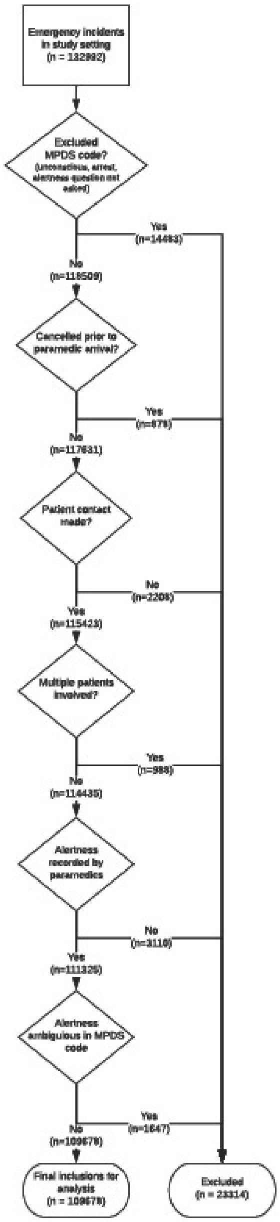

Figure 2. Flow diagram for inclusion and exclusion criteria

Results

Of the 132,992 incidents involving an emergency ambulance call to SJWA, 109,678 met the study inclusion criteria (82.47%) (Figure 2). In total, 19,359 incidents (17.65%) were dispatched as 'not alert', while there was a total of 1833 incidents (1.67%) where paramedics recorded the patient as not alert on arrival. Overall sensitivity was 69.94% (95% CI: 67.78-72.03%), and specificity was 83.24% (95% CI: 83.01-83.46%) (Table 3).

Of the 19,359 incidents where the patient was dispatched as 'not alert', 1282 were recorded by paramedics as being not alert. Therefore, the overall PPV was 6.62% (95% CI: 6.28-6.98%) (Table 3). Of the 18,077 false positive cases, the most common MPDS chief complaints were unconscious/fainting (near) (18.68%), breathing problems (12.07%), falls (11.88%) and sick person (11.70%) (Table 4).

Of the 90,319 incidents where the patient was dispatched as 'alert', 89,768 were found to be alert on paramedic arrival. Therefore, the overall NPV was 99.39% (95% CI: 99.34-99.44%) (Table 3). Of the 551 false negative cases (dispatched as alert, but recorded by paramedics as not alert), the most common MPDS chief complaints were sick person (28.86%), breathing problems (21.60%), falls (10.16%) and overdose/poisoning (8.17%) (Table 4).

There was significant variation in PPV between MPDS chief complaints (χ^2=216.64, df=18, $p<0.0001$), and significant variation in NPV between chief complaints (χ^2=355.09, df=18, $p<0.0001$) (Table 5).

Of the 18,077 false positive cases (dispatched as not alert but found to be alert by paramedics), 2831 (15.6%) were recorded by paramedics as 'drowsy' and 2493 (13.8%) as 'confused' (ie. SJWA subsets of the AVPU alert category) (Table 3). Conversely, of the 5282 patients recorded by paramedics as drowsy, 2831 (53.6%) were dispatched as not alert; and of the 7332 patients recorded by paramedics as confused, 2943 (40.1%) were dispatched as not alert (Table 3).

The sensitivity analysis showed that changing the definition of not alert to include patients categorised by paramedics as drowsy or confused resulted in an increase of PPV to 33.12% (95% CI: 33.46-34.80%) and specificity to 86.67% (95% CI: 86.45-86.89%) but a decrease in NPV to 91.82% (95% CI: 91.64-91.99%) and sensitivity to 47.19% (95% CI: 46.37-48.03%).

Discussion

This study found high levels of inaccuracy between dispatch determination of alertness and what paramedics found on scene. There were more than 10 times as many cases dispatched as not alert than the number recorded by paramedics as not alert on arrival at the scene. This system appears highly risk averse in the detection of not alert patients, with a low PPV (6.62%) and high NPV (99.39%).

Typically, the aim of a risk averse approach is to achieve a high level of sensitivity (ie. to ensure positive cases are identified) (3). However, despite a high ratio of not alert dispatch to not alert patients on scene, the study found a modest sensitivity in the detection of not alert patients (69.94%). Therefore, of all patients found to be not alert on scene, three in every 10 were dispatched as alert (ie. false negatives). Rather than this being a truly over-triaged system per se (in terms of low PPV and high sensitivity to detect not alert patients), this would be better described as a risk averse system that is not achieving high sensitivity. This shows that both false negatives, and false positives are important in relation to determination of patients being not alert. Furthermore, when a system-wide sensitivity analysis on the definition of paramedic-determined alertness was applied (excluding drowsy and confused patients from the definition of alert patients), sensitivity was only lower, at 47%.

Conscious state exists on a spectrum, with various scales used to measure it, eg. the AVPU from 'alert to unresponsive' or Glasgow Coma Scale (27) from 15 to 3. Asking 'is s/he completely alert?' requires the caller to give a yes or no answer to a question that lies on a continuum. The caller (or EMD if a binary answer is not provided by the caller), must therefore judge where to make the cut-off between alert and not alert. Evidence for the subjective nature of this decision may lie in the high levels of variation observed among patients recorded by paramedics as drowsy or confused (subsets of alert on the AVPU scale), with 53.6% of drowsy patients, and 36.2% of confused patients having been dispatched as not alert.

The study found statistically significant variation between chief complaints in PPV – the proportion of not alert patients (on dispatch) being found to be not alert by paramedics. Some of the highest PPVs were in complaints where an altered conscious state is a likely symptom: diabetic problems (PPV 10.94%), overdose/poisoning (PPV 9.43%), stroke (PPV 9.84%) and unconscious/fainting (near) (PPV 8.01%). Conversely, some of the lowest PPVs were in complaints of pain: abdominal pain (PPV 1.78%), chest pain (PPV 2.46%), headache (PPV 1.44%) and back pain (PPV 0%). Although some of this may be explained by the statistical calculation of PPV where a higher incidence of a condition will automatically increase the PPV, the study also found much higher sensitivity (which is independent of incidence) in most of these complaints with high PPV, and below average sensitivity in those with low PPV. It stands to intuitive reason that where an altered conscious state is more likely to be the trigger for the emergency call, there will be a higher incidence of a patient being correctly identified as being not alert, whereas a patient complaining of pain would generally have some level of alertness to be able to communicate this. Targeted research into complaints with particularly low PPV is suggested as this may highlight areas for future improvement in triage questioning to reduce the number of false positives in identifying not alert patients.

There was also statistically significant variation between chief complaints in NPV – the proportion of alert patients (on dispatch) found to be alert by paramedics. The chief complaints of breathing problems, overdose/poisoning, sick person, and stroke were highlighted as having a lower than average NPV. That is, these chief complaints had a higher than average proportion of alert patients (on dispatch) found to be not alert by paramedics (ie. higher false omission rate, 1-NPV). This highlights chief complaints that may be suitable targets for research into reducing the number of false negatives.

For more accurate assessment of alertness, different or further questioning may be required. This could take the form of a secondary triage system after the initial triage interview (2) or asking different questions in the initial triage sequence. A recent study found that using the clarifier question (asked if the caller

		Paramedic assessment on arrival			
		Not alert	Alert	Total	
EMD triage assessment	Not alert	1282: 503 voice response; 584 pain response; 195 unresponsive	18,077: 12,753 alert; 2831 drowsy; 2493 confused	19,359	PPV = 6.62% (95% CI: 6.28-6.98%)
	Alert	551: 238 voice response; 207 pain response; 106 unresponsive	89,768: 82,928 alert; 2451 drowsy; 4389 confused	90,319	NPV = 99.39% (95% CI: 99.34-99.44%)
	Total	1833	107,845	109,678	
		Sensitivity = 69.94% (95% CI: 67.78-72.03%)	Specificity = 83.24% (95% CI: 83.01-83.46%)		

Table 3. Diagnostic accuracy of EMD-determination vs on-scene paramedic-determination of patient alterness

Table 4. EMD assessment vs paramedic findings on arrival for patient alertness, by MPDS chief complaint

MPDS chief complaint	Total cases	Not alert dispatch	% not alert dispatch	Not alert at scene	% not alert at scene	True positive	False positive	False negative	True negative
01 Abdo. pain/problems	5508	506	9.19%	15	0.27%	9	497	6	4996
02 Allergies/envenom.	1778	239	13.44%	17	0.96%	9	230	8	1531
03 Animal bites/attacks	95	6	6.32%	0	0.00%	0	6	0	89
04 Assault/sex assault	2134	370	17.34%	23	1.08%	12	358	11	1753
05 Back pain	2483	112	4.51%	1	0.04%	0	112	1	2370
06 Breathing problems	13,579	2370	17.45%	307	2.26%	188	2182	119	11,090
07 Burns/explosion	250	3	1.20%	2	0.80%	0	3	2	245
08 CO/Inh./HAZ/CBRN	52	16	30.77%	2	3.85%	2	14	0	36
10 Chest pain	16,162	1016	6.29%	50	0.31%	25	991	25	15,121
11 Choking	107	10	9.35%	2	1.87%	1	9	1	96
13 Diabetic problems	1278	850	66.51%	96	7.51%	93	757	3	425
14 Drowning/diving/SCUBA	31	15	48.39%	1	3.23%	1	14	0	16
15 Electroc./lightning	31	2	6.45%	0	0.00%	0	2	0	29
16 Eye problems	177	8	4.52%	2	1.13%	1	7	1	168
17 Falls	16,568	2245	13.55%	152	0.92%	96	2149	56	14,267
18 Headache	1606	277	17.25%	7	0.44%	4	273	3	1326
19 Heart probs/AICD.	3852	386	10.02%	42	1.09%	30	356	12	3454
20 Heat/cold exposure	57	24	42.11%	2	3.51%	2	22	0	33
21 Haemorrhage/lacer.	5092	547	10.74%	53	1.04%	25	522	28	4517
23 Overdose/poisoning	3269	1294	39.58%	167	5.11%	122	1172	45	1930
25 Psych./suicide attempt	5597	994	17.76%	59	1.05%	45	949	14	4589
26 Sick person	14,309	2269	15.86%	313	2.19%	154	2115	159	11,881
27 Stab/gunshot/penet.	215	8	3.72%	2	0.93%	1	7	1	206
28 Stroke	3932	1616	41.10%	186	4.73%	159	1457	27	2289
29 Traffic/transport.	1493	69	4.62%	11	0.74%	4	65	7	1417
30 Traumatic injuries	3388	436	12.87%	13	0.38%	5	431	8	2944
31 Unconscious/fainting	6635	3671	55.33%	308	4.64%	294	3377	14	2950
Total	109,678	19,359	17.65%	1833	1.67%	1282	18,077	551	89,768

Table 5. Measures of diagnostic accuracy, by MPDS chief complaint

MPDS chief complaint	Sensitivity as % (and 95% CI)	Specificity as % (and 95% CI)	PPV as % (and 95% CI)	χ^2 (PPV)	NPV as % (and 95% CI)	χ^2 (NPV)
01 Abdo. pain/problems	60.0 (32.3-83.7)	91.0 (90.2-91.7)	1.8 (0.8-3.3)	19.20	99.9 (99.7-100.0)	19.82
02 Allergies/envenom.	52.9 (27.8-77.0)	86.9 (85.3-88.5)	3.8 (1.7-7.0)	3.15	99.5 (99.0-99.8)	0.21
03 Animal bites/attacks	N/A	93.7 (86.8-97.6)	0.0 (0.0-45.9)	*	100.0 (95.9-100.0)	*
04 Assault/sexual assault	52.2 (30.6-73.2)	83.0 (81.4-84.6)	3.2 (1.7-5.6)	6.83	99.4 (98.9-99.7)	0.01
05 Back pain	0.0 (0.0-97.5)	95.5 (94.6-96.3)	0.0 (0.0-3.2)	7.94	100.0 (99.8-100.0)	12.61
06 Breathing problems	61.2 (55.5-66.7)	83.6 (82.9-84.2)	7.9 (6.9-9.1)	6.58	98.9 (98.7-99.1)	37.70
07 Burns/explosion	0.0 (0.0-84.2)	98.8 (96.5-99.7)	0.0 (0.0-70.8)	*	99.2 (97.1-99.9)	*
08 CO/Inh./HAZ./CBRN	100.0 (15.8-100.0)	72.0 (57.5-83.8)	12.5 (1.6-38.3)	*	100.0 (90.3-100.0)	*
10 Chest pain	50.0 (35.5-64.5)	93.8 (93.5-94.2)	2.5 (1.6-3.6)	28.46	99.8 (99.8-99.9)	49.47
11 Choking	50.0 (1.3-98.7)	91.4 (84.4-96.0)	10.0 (0.3-44.5)	*	99.0 (94.4-100.0)	*
13 Diabetic problems	96.9 (91.1-99.4)	36.0 (33.2-38.8)	10.9 (8.9-13.2)	25.64	99.3 (98.0-99.9)	0.06
14 Drown./diving/SCUBA	100.0 (2.5-100.0)	53.3 (34.3-71.7)	6.7 (0.2-31.9)	*	100.0 (79.4-100.0)	*
15 Electroc./lightning	N/A	93.5 (78.6-99.2)	0.0 (0.0-84.2)	*	100.0 (88.1-100.0)	*
16 Eye problems	50.0 (1.3-98.7)	96.0 (91.9-98.4)	12.5 (0.3-52.7)	*	99.4 (96.7-100.0)	*
17 Falls	63.2 (55.0-70.8)	86.9 (86.4-87.4)	4.3 (3.5-5.2)	19.98	99.6 (99.5-99.7)	11.34
18 Headache	57.1 (18.4-90.1)	82.9 (81.0-84.7)	1.4 (0.4-3.7)	12.01	99.8 (99.3-100.0)	3.24
19 Heart probs./AICD.	71.4 (55.4-84.3)	90.7 (89.7-91.6)	7.8 (5.3-10.9)	0.83	99.7 (99.4-99.8)	3.98
20 Heat/cold exposure	100.0 (15.8-100.0)	60.0 (45.9-73.0)	8.3 (1.0-27.0)	*	100.0 (89.4-100.0)	*
21 Haemorrhage/lacer.	47.2 (33.3-61.4)	89.6 (88.8-90.5)	4.6 (3.0-6.7)	3.72	99.4 (99.1-99.6)	0.00
23 Overdose/poisoning	73.1 (65.7-79.6)	62.2 (60.5-63.9)	9.4 (7.9-11.2)	16.48	97.7 (97.0-98.3)	90.67
25 Psych./suicide attempt	76.3 (63.4-86.4)	82.9 (81.8-83.8)	4.5 (3.3-6.0)	7.06	99.7 (99.5-99.8)	7.10
26 Sick person	49.2 (43.5-54.9)	84.9 (84.3-85.5)	6.8 (5.8-7.9)	0.10	98.7 (98.5-98.9)	100.25
27 Stab/gunshot/penet.	50.0 (1.3-98.7)	96.7 (93.3-98.7)	12.5 (0.3-52.7)	*	99.5 (97.3-100.0)	*
28 Stroke	85.5 (79.6-90.2)	61.1 (59.5-62.7)	9.8 (8.4-11.4)	27.04	98.8 (98.3-99.2)	11.80
29 Traffic/transport.	36.4 (10.9-69.2)	95.6 (94.4-96.6)	5.8 (1.6-14.2)	0.08	99.5 (99.0-99.8)	0.33
30 Traumatic injuries	38.5 (13.9-68.4)	87.2 (86.1-88.3)	1.1 (0.4-2.7)	21.14	99.7 (99.5-99.9)	5.60
31 Unconscious/fainting	95.5 (92.5-97.5)	46.6 (45.4-47.9)	8.0 (7.2-8.9)	11.41	99.5 (99.2-99.7)	0.93
Total	69.9 (67.8-72.0)	83.2 (83.0-83.5)	6.6 (6.3-7.0)	217.64	99.4 (99.3-99.4)	355.09

* χ^2 values not calculated for rows with expected values <1

does not understand the initial question) 'is s/he responding appropriately?' in a system using MPDS for triage, achieved better caller understanding (28). Criteria based dispatch, another triage algorithm used internationally, has the question 'can the patient respond to you and follow simple commands?' (29). It may be that such wording yields more accurate responses, but ultimately none of these questions have been validated. Further research is suggested into the most linguistically optimal questioning to achieve clinically useful answers from the caller.

This study fills an important knowledge gap (18). The two previous studies (19,20) examining the accuracy of conscious state determination in dispatch were based on the distinction between conscious versus unconscious patients. However, given that alertness among conscious patients is also a key component of emergency medical dispatch systems such as the MPDS, it is essential to understand its accuracy. The inventor of the MPDS algorithm has described 'determining true non-alertness' as one of the holy grails requiring further research (30,31). To the authors' knowledge, this study is the first to undertake a system-wide analysis of this issue.

Limitations

The study compared the determination of a patient's conscious state at the time of the emergency call to their conscious state when attended by paramedics. There is necessarily a time delay between these two measures, during which a patient could deteriorate or recover. It is not possible to know the patient's true conscious state at the exact time of the call; therefore, this study considers the accuracy as a predictor of what will be found on paramedic arrival.

This study compared the reported conscious state of the patient as selected by the EMD at the time of the call, however, it did not analyse audio of call recordings. This could be a valuable avenue for future research to further inform what is said by callers and how this relates to the patient's condition. With the scale of data in this study it was not practical to determine the relationship between caller and patient for individual calls and how this relates to accuracy, however this could also be an informative avenue for future research.

Conclusion

This study found that dispatch determination of patient altered conscious state yields a high NPV but a low PPV, with more than 10 times as many cases dispatched as not alert than patients who are not alert on scene. Despite this, the system did not achieve high sensitivity, with three out of every 10 patients who were not-alert on the scene being dispatched as alert. There were significant differences in the positive and negative predictive values between different chief complaints. Further research is suggested into the factors that affect the accuracy of EMD determination of patient conscious state, including the phrasing used by callers and EMDs.

Competing interests

The authors of this paper report no competing interests. Each author of this paper has completed the ICMJE conflict of interest statement. JB and AW are employed full time by SJWA as ambulance paramedic and operations manager respectively. JF receives partial research funding from SJWA, and both JF and SB have adjunct research appointments with SJWA.

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5.4. Further results and discussion based on alternative definition

The published manuscript used a definition of "Alert" for the reference standard based on the AVPU assessment, where anything above Voice Response was considered Alert. This meant patients assessed as Confused or Drowsy were treated as Alert for this purpose. I conducted a secondary sensitivity analysis based on an alternative definition, where patients assessed by paramedics as Confused and Drowsy were instead treated as Not Alert for the reference standard. This was completed on the same data set as the original published analysis, with the same included cases. This section reports on that secondary analysis.

In total, 19,359 incidents (17.65%) were dispatched as "not alert", while there was a total of 13,997 incidents (12.76%) where paramedics recorded the patient as Not Alert on arrival. Overall sensitivity was 47.20% (95% CI: 46.37%-48.03%), and specificity was 86.67% (95% CI: 86.45%-86.89%) (Table 11).

Table 11: Diagnostic accuracy of EMD -determination, versus on-scene paramedic-determination of patient alertness

		Paramedic assessment on arrival			
		Not Alert	Alert	TOTAL	
EMD triage assessment	Not Alert	**6606** 2493 Confused; 2831 Drowsy; 503 Voice Response; 584 Pain Response; 195 Unresponsive	**12,753** 12,753 Alert	**19,359**	PPV = 34.12% (95% CI: 33.46%-34.80%)
	Alert	**7391** 4389 Confused; 2451 Drowsy; 238 Voice Response; 207 Pain Response; 106 Unresponsive	**82,928** 82,928 Alert	**90,319**	NPV = 91.82% (95% CI: 91.64%-91.99%)
	TOTAL	**13,997**	**95,681**	**109,678**	
		Sensitivity = 47.20% (95% CI: 46.37%-48.03%)	Specificity = 86.67% (95% CI: 86.45%-86.89%)		

Of the 19,359 incidents where the patient was dispatched as Not Alert, 6,606 were recorded by paramedics as being not alert. Thus, the overall PPV was 34.12% (95% CI: 33.46%-34.80%) (Table 11). Of the 12,753 false positive cases, the most common MPDS chief complaints were

Unconscious/Fainting (near) (18.87%), Breathing problems (12.52%), Falls (11.16%) and Sick person (11.04%) (Table 12).

Of the 90,319 incidents where the patient was dispatched as alert, 82,928 were found to be alert on paramedic arrival. Thus, the overall NPV was 91.82% (95% CI: 91.64%-91.99%) (Table 11). Of the 7,391 false negative cases (dispatched as alert, but recorded by paramedics as not alert), the most common MPDS chief complaints were Falls (23.88%), Sick person (22.85%), Breathing problems (10.43%), and Psychiatric/suicide attempt (6.64%) (Table 12).

There was significant variation in PPV between MPDS chief complaints ($\chi 2$=574.53, d.f.=18, P<0.0001), and significant variation in NPV between chief complaints ($\chi 2$=2,577.1, d.f.=18, P<0.0001) (Table 13). Nine protocols were excluded from the $\chi 2$ analysis that had been excluded from the primary analysis due to small denominators. This had the effect of removing all rows with an expected value of <5[56], and no rows were removed that did not have such an expected value.

Of the 7,391 false negative cases (dispatched as Alert but found to be Not Alert by paramedics), 4,389 (59.3%) were recorded by paramedics and as Confused and 2,451 (33.2%) as Drowsy (Table 11). Conversely, of the 6,882 patients recorded by paramedics as Confused, 2,943 (36.2%) were dispatched as Not Alert; and of the 5,282 patients recorded by paramedics as Drowsy, 2,831 (53.6%) were dispatched as Not Alert (Table 11).

The original published analysis found high levels of over-triage (with a PPV of only 6.62%), however this over-triage does not translate into being a risk-averse system as the sensitivity was only 69.94% (i.e., 30% of actual altered conscious state patients are not detected through conscious state questioning). The alternative definition in this analysis continued on that theme. While over-triage was considerably lower (PPV 34.12%) under the alternative definition, it is still a high rate of false positives. Sensitivity, on the other hand, reduced to 47.20%, meaning more patients with altered conscious states are missed than are detected.

Under the new definition, the individual protocols with the highest PPV changed slightly – Overdose/Poisoning (49.54%), Diabetic problem (45.29%) and Stroke (41.65%) remained very high, but Traffic/Transportation Accident (40.58%) also showed a high PPV which did not appear in the original analysis. While the former three are protocols on which you would expect an altered conscious state to be the reason for the call, as per the original analysis, this is not the case on the Traffic accident protocol. This result would suggest callers are more likely to classify patients in a traffic accident who are drowsy or confused as Not Alert on an emergency call, than for other presentations. Reasons for this are unknown, it is possible that callers in these circumstances are more likely to be strangers to the patient and thus not be familiar with their normal conscious state, so more likely to treat anything but completely alert as Not Alert; however, this would require further research to validate.

Protocols with the lowest PPV also remained mostly unchanged from the previous analysis, with Chest Pain (15.35%), Abdominal Pain (15.61%), Headache (20.58%) and Back Pain (24.11%) continuing to be amongst the lowest. Allergies/Envenomation (23.85%) also had a notably low PPV under this definition.

5.4.1. Relationship between PPV and Prevalence

The positive predictive value (post-test probability) of a test is strongly influenced by the prevalence of the condition (pre-test probability)[57]. The PPV increases as the prevalence increases, but the NPV decreases. Conversely, the PPV decreases as the prevalence decreases, while the NPV increases. In terms of my study, the prevalence of being 'not alert' is the proportion of patients found to be below the selected conscious state threshold in either the original or alternative definition on paramedic assessment.

In both analyses (i.e. with alertness defined using the AVPU scale, which includes confused and drowsy patients as part of the Alert category; and the sensitivity analysis based on the ACDU scale where confused and drowsy patients were treated as Not Alert), some but not all of the variation in PPV may be explained by the prevalence of not-alert patients. As identified in the manuscript for this study, higher PPV is seen (in both definitions of alertness) on MPDS protocols for presenting complaints where an altered conscious state may be an expected symptom. The higher PPV is likely related to the higher prevalence of altered conscious states found on these protocols. This does not explain the entirety of the differences in PPV between protocols, however. For example, the Traffic/Transportation Accident protocol identified earlier for the alternative analysis has a PPV (post-test probability) of 40.6%, whereas the prevalence of altered conscious states (pre-test probability) on this protocol is only 6.63% This means there is a relative performance of the post-test probability being 6.12 times the pre-test probability – a performance much higher than the overall performance seen.

Overall, the original definition of alertness (using AVPU and treating confused and drowsy as Alert) had a better relative performance than the alternative – with the post-test-probability (PPV) for the whole data set being 3.9 times that of the pre-test probability (prevalence), compared to 2.7 times for the alternative definition.

Table 12: EMD assessment versus paramedic findings on arrival for patient alertness, by MPDS protocol

MPDS Protocol	Total Cases	Not Alert Dispatch	% Not Alert Dispatch	Not Alert at scene	% Not Alert at scene (Prevalence)	True Pos.	False Pos.	False Neg.	True Neg.
01 Abdo. pain/problems	5508	506	9.19%	262	4.76%	79	427	183	4819
02 Allergies/Envenom.	1778	239	13.44%	105	5.91%	57	182	48	1491
03 Animal bites/attacks	95	6	6.32%	1	1.05%	0	6	1	88
04 Assault/Sex. assault	2134	370	17.34%	245	11.48%	95	275	150	1614
05 Back Pain	2483	112	4.51%	89	3.58%	27	85	62	2309
06 Breathing problems	13,579	2370	17.45%	1544	11.37%	773	1597	771	10,438
07 Burns/Explosion	250	3	1.20%	6	2.40%	0	3	6	241
08 CO/Inh/HAZ./CBRN	52	16	30.77%	7	13.46%	4	12	3	33
10 Chest Pain	16,162	1016	6.29%	576	3.56%	156	860	420	14,726
11 Choking	107	10	9.35%	8	7.48%	3	7	5	92
13 Diabetic problems	1278	850	66.51%	427	33.41%	385	465	42	386
14 Drowning/Diving/SCUBA	31	15	48.39%	2	6.45%	2	13	0	16
15 Electroc./Lightning	31	2	6.45%	0	0.00%	0	2	0	29
16 Eye Problems	177	8	4.52%	6	3.39%	2	6	4	165
17 Falls	16,568	2245	13.55%	2587	15.61%	822	1423	1765	12,558
18 Headache	1606	277	17.25%	125	7.78%	57	220	68	1261
19 Heart Probs/AICD.	3852	386	10.02%	265	6.88%	116	270	149	3317
20 Heat/Cold exposure	57	24	42.11%	12	21.05%	9	15	3	30
21 Haemorrhage/Lacer.	5092	547	10.74%	482	9.47%	157	390	325	4220
23 Overdose/Poisoning	3269	1294	39.58%	1088	33.28%	641	653	447	1528
25 Psych./Suicide attempt	5597	994	17.76%	772	13.79%	281	713	491	4112
26 Sick Person	14,309	2269	15.86%	2550	17.82%	861	1408	1689	10,351
27 Stab/Gunshot/Penet.	215	8	3.72%	8	3.72%	1	7	7	200
28 Stroke	3932	1616	41.10%	968	24.62%	673	943	295	2021
29 Traffic/Transport.	1493	69	4.62%	99	6.63%	28	41	71	1353
30 Traumatic Injuries	3388	436	12.87%	265	7.82%	113	323	152	2800
31 Unconscious/Fainting	6635	3671	55.33%	1498	22.58%	1264	2407	234	2730
Total	**109,678**	**19,359**	**17.65%**	**13,997**	**12.76%**	**6606**	**12,753**	**7391**	**82,928**

Table 13: Measures of diagnostic accuracy, by MPDS protocol

MPDS Chief Complaint	Sensitivity as % (and 95% CI)	Specificity as % (and 95% CI)	PPV as % (and 95% CI)	χ^2 (PPV)	NPV as % (and 95% CI)	χ^2 (NPV)
01 Abdo. pain/problems	30.2 (24.7-36.1)	91.9 (91.1-92.6)	15.6 (12.6-19.1)	77.13	96.3 (95.8-96.8)	136.29
02 Allergies/Envenom.	54.3 (44.3-64.0)	89.1 (87.5-90.6)	23.8 (18.6-29.8)	11.22	96.9 (95.9-97.7)	52.53
03 Animal bites/attacks	0.0 (0.0-97.5)	93.6 (86.6-97.6)	0.0 (0.0-45.9)	*	98.9 (93.9-100.0)	*
04 Assault/Sex. assault	38.8 (32.6-45.2)	85.4 (83.8-87.0)	25.7 (21.3-30.4)	11.75	91.5 (90.1-92.8)	0.24
05 Back Pain	30.3 (21.0-41.0)	96.4 (95.6-97.2)	24.1 (16.5-33.1)	5.00	97.4 (96.7-98.0)	97.84
06 Breathing problems	50.1 (47.5-52.6)	86.7 (86.1-87.3)	32.6 (30.7-34.5)	2.40	93.1 (92.6-93.6)	25.40
07 Burns/Explosion	0.0 (0.0-45.9)	98.8 (96.4-99.7)	0.0 (0.0-70.8)	*	97.6 (94.8-99.1)	*
08 CO/Inh/HAZ./CBRN	57.1 (18.4-90.1)	73.3 (58.1-85.4)	25.0 (7.3-52.4)	*	91.7 (77.5-98.2)	*
10 Chest Pain	27.1 (23.5-30.9)	94.5 (94.1-94.8)	15.4 (13.2-17.7)	159.22	97.2 (97.0-97.5)	590.04
11 Choking	37.5 (8.5-75.5)	92.9 (86.0-97.1)	30.0 (6.7-65.2)	*	94.8 (88.4-98.3)	*
13 Diabetic problems	90.2 (86.9-92.8)	45.4 (42.0-48.8)	45.3 (41.9-48.7)	47.18	90.2 (87.0-92.8)	1.51
14 Drown./Diving/SCUBA	100.0 (15.8-100.0)	55.2 (35.7-73.6)	13.3 (1.7-40.5)	*	100.0 (79.4-100.0)	*
15 Electroc./Lightning	N/A	93.5 (78.6-99.2)	0.0 (0.0-84.2)	*	100.0 (88.1-100.0)	*
16 Eye Problems	33.3 (4.3-77.7)	96.5 (92.5-98.7)	25.0 (3.2-65.1)	*	97.6 (94.1-99.4)	*
17 Falls	31.8 (30.0-33.6)	89.8 (89.3-90.3)	36.6 (34.6-38.6)	6.20	87.7 (87.1-88.2)	326.67
18 Headache	45.6 (36.7-54.7)	85.1 (83.2-86.9)	20.6 (16.0-25.8)	22.61	94.9 (93.6-96.0)	16.63
19 Heart Probs/AICD.	43.8 (37.7-50.0)	92.5 (91.6-93.3)	30.1 (25.5-34.9)	2.85	95.7 (95.0-96.4)	69.60
20 Heat/Cold exposure	75.0 (42.8-94.5)	66.7 (51.0-80.0)	37.5 (18.8-59.4)	*	90.9 (75.7-98.1)	*
21 Haemorrhage/Lacer.	32.6 (28.4-37.0)	91.5 (90.7-92.3)	28.7 (24.9-32.7)	7.15	92.8 (92.1-93.6)	6.45
23 Overdose/Poisoning	58.9 (55.9-61.9)	70.1 (68.1-72.0)	49.5 (46.8-52.3)	136.74	77.4 (75.5-79.2)	548.83
25 Psych./Suicide attempt	36.4 (33.0-39.9)	85.2 (84.2-86.2)	28.3 (25.5-31.2)	15.15	89.3 (88.4-90.2)	37.79
26 Sick Person	33.8 (31.9-35.6)	88.0 (87.4-88.6)	37.9 (35.9-40.0)	14.75	86.0 (85.3-86.6)	547.46
27 Stab/Gunshot/Penet.	12.5 (0.3-52.7)	96.6 (93.2-98.6)	12.5 (0.3-52.7)	*	96.6 (93.2-98.6)	*
28 Stroke	69.5 (66.5-72.4)	68.2 (66.5-69.9)	41.6 (39.2-44.1)	40.68	87.3 (85.8-88.6)	63.93
29 Traffic/Transport.	28.3 (19.7-38.2)	97.1 (96.0-97.9)	40.6 (28.9-53.1)	1.28	95.0 (93.8-96.1)	19.37
30 Traumatic Injuries	42.6 (36.6-48.8)	89.7 (88.5-90.7)	25.9 (21.9-30.3)	13.06	94.9 (94.0-95.6)	36.17
31 Unconscious/Fainting	84.4 (82.4-86.2)	53.1 (51.8-54.5)	34.4 (32.9-36.0)	0.16	92.1 (91.1-93.1)	0.33
Total	**47.2 (46.4-48.0)**	**86.7 (86.5-86.9)**	**34.1 (33.5-34.8)**	**574.53**	**91.8 (91.6-92.0)**	**2577.10**

Note: * $\chi 2$ values not calculated for rows excluded from original analysis. See Appendix 3 for $\chi 2$ calculations.

5.5. Summary

This retrospective study of 109,678 emergency ambulance calls and associated attendances found that the conscious state questioning presently used in triage of emergency calls in Western Australia produces high rates of over-triage. It is not, however, a truly risk-averse system as may be expected with over-triage, as it does not achieve high sensitivity. This study addresses the knowledge gap identified in the systematic review conducted in Chapter 4, which identified no studies measuring the accuracy of determination of altered conscious states in conscious patients during an emergency call. This study is, to my knowledge, the first and only study to date undertaking a system-wide analysis of this.

While analysis with an alternative definition of "alert" may change the numbers themselves, the overall finding remained, of high levels of over-triage with poor sensitivity. There are significant differences between individual protocols, with protocols where an altered conscious state would be an expected symptom seeing higher PPV.

Further research is recommended into improving the accuracy of conscious state assessment during emergency calls. This has previously been identified as a priority, with the inventor of the MPDS algorithm describing "determining true non-alertness" as one of the "holy grails" requiring further research[21, 58]. Any alternative questioning will need to be designed to target an appropriate level of consciousness.

While two alternative thresholds of conscious state were analysed in this study, the question of the appropriate threshold from a dispatch triage perspective is a clinical question based on which levels are more predictive of high acuity patients. Further research is recommended to answer this question. To this end I conducted a further study investigating the association between a patients' presenting conscious state and their acuity in Chapter 6.

Chapter 6. Analysis of the association between presenting conscious state and acuity

6.1. Overview

This chapter presents the findings of the second analytical study conducted for the thesis. This study analysed the relationship between a patient's presenting conscious state on arrival of paramedics, and whether they were considered a high acuity patient.

The previous study in Chapter 5 analysed the accuracy of the Alert/Not Alert questioning in primary triage of an emergency call compared to paramedic findings of conscious state on arrival. It found that the conscious state questioning presently used in triage of emergency calls produces high rates of over-triage. It is not, however, a truly risk-averse system as may be expected with over-triage, as it does not achieve high sensitivity.

Conscious state exists on a spectrum rather than a binary state of alert or not alert. Between completely alert and unconscious there are many degrees of change. This can be measured in with scales such as AVPU or GCS. My previous chapter addressed ambiguities in the threshold level of alertness for determining Alert or Not Alert. While the primary analysis was based on AVPU (with Confused and Drowsy treated as above Voice Response, and thus classed as Alert), an alternative threshold was used for any change in conscious state, with Confused and Drowsy (which would be considered Alert on AVPU) considered Not Alert. It is unclear what is the clinically appropriate level to look for when designing a triage system.

This study compares the patient's presenting conscious state on arrival of paramedics with their acuity, with a view to understanding the relationship and using this information to determine an appropriate threshold that can be targeted in dispatch. It also analyses how the predictive value of conscious state to acuity may differ between reasons for the emergency call, so that better conscious state assessment may be prioritised for the right types of calls where there is clinician re-assessment of calls (secondary triage) in a dispatch setting.

The study is reported in the following article which was published in the *Australasian Emergency Care* journal:

Belcher J, Finn J, Whiteside A, Ball S. Association between initial presenting level of consciousness and patient acuity – A potential application for secondary triage in emergency ambulance calls. *Australasian Emergency Care*. 2023;26(3):199-204. doi:10.1016/j.auec.2022.11.002[39].

The corrected proof is reproduced in the following pages of this chapter after the detailed methodology. The article is reproduced with permission, and copyright is held by the College of Emergency Nurses Australasia (2022).

6.2. Detailed Methodology

This section provides detail on the methodology of this study including rationale for some choices made while designing the study.

6.2.1. Study Design

The study was a retrospective observational study of the association between paramedic determined conscious state on arrival to a patient, and their eventual acuity based on paramedic assessment and management. It was a population study of all patients attended by paramedics in the Perth metropolitan area in a 1-year period.

6.2.2. Data sources and determination of conscious state and patient acuity

Patient conscious state and acuity were sourced and synthesised from SJWA Electronic Patient Care Record (ePCR) data as follows:

6.2.2.1. Determination of conscious state

As detailed in the Background chapter and methodology for the previous study, paramedics enter an initial conscious state on arrival at the patient into their ePCR in a six-level descriptive scale consisting of Alert, Confused, Drowsy, Voice Response, Pain Response and Unresponsive. I used this entry as the comparator for paramedic findings.

Along with the reasons in the previous study for using this descriptive scale as opposed to GCS, the descriptors better align to the telephone triage environment that this study seeks to inform. A layperson on an emergency call may describe a patient's conscious state (and use words similar to one of these descriptors, or be prompted by the descriptors), however is unlikely to be able to produce a GCS score.

6.2.2.2. Determination of patient acuity

Patient acuity was synthesised from paramedic assessment and management as recorded in ePCR. The ePCR system stores data input for paramedic assessment and management as History, Assessment and Management (HAM) codes. In 2019 SJWA created a High Acuity Filter which consisted of a list of HAM codes, the presence of which would indicate a high acuity patient. This was completed as part of a process to review dispatch priorities to better align the priority allocated to MPDS determinants to patient acuity. This work was done by a committee consisting of SJWA clinicians and communications staff, as well as external emergency physician and consumer representation. The process followed a methodology published by Andrew et al[9] used for the same purpose of aligning ambulance response priorities to patient acuity in the Victorian ambulance service.

The high acuity filter includes paramedic assessment items (such as obstructed airway, laboured breathing), history (such as mechanism of injury or entrapment in a motor vehicle accident) and management (specific clinical interventions such as inter-osseous cannulation, or medications such as Adrenaline or Ketamine). The full high acuity filter is reproduced at Appendix 4. Patients were considered high acuity if any HAM code on the SJWA high acuity filter was selected in their patient care record, and lower acuity otherwise. As discussed in the manuscript, a sufficiently low total GCS or component score could trigger a patient to be considered high acuity. I did consider removing these codes to prevent circular reasoning (i.e. of paramedic-determined alertness being predictive of paramedic-determined GCS), however I decided to keep the High Acuity Filter as designed by the expert committee as it is clinically reasonable to consider these patients to be at an extreme end of acuity. In relation to the GCS thresholds used in the High Acuity Filter, a GCS Verbal component score of 2 or less (making incomprehensible sounds or no verbal response at all) or a Motor component score of 3 or less (abnormal flexion, abnormal extension or no motor response at all) are indicative of a patient with a significant neurological compromise. In contrast, the categorisation of patients as ‘not-alert’ could include many patients who do not have GCS scores or components this low. It is also important to remember that whereas paramedic-determined alertness was based on initial assessment, the High Acuity Filter is based on patient data up to the time of hospital handover, with the possibility that patient conscious state deteriorates sufficiently to trigger the high acuity filter. In this predictive sense, the association between initial alertness and lowest prehospital GCS is not necessarily circular.

While the SJWA high acuity filter is not formally validated, it follows a published and peer reviewed methodology[9]. It has been previously used in a peer reviewed and published study[59].

I considered using patient observations (vital signs) as a measure of acuity, as either extreme variation from normal in a single observation, or aggregate variations in multiple observations. This would have been achieved by summarising deviation of observations from normal using a validated observation-based Early Warning Score (EWS) system as the outcome variable. I specifically considered NEWS2[60] which is well recognised and validated in the prehospital field[61, 62]. However, I ultimately decided against this for several reasons:

- Observation-based early warning score systems are used to predict deterioration. Using patient conscious state to predict an EWS above a certain threshold, would effectively be predicting a predictor rather than the event (a high acuity patient) itself.
- Because these tools are based on formal observation sets, there may be some delay prior to a set of observations being entered and the first set of observations may not be what was seen on arrival of paramedics if immediate management was performed.
- If full observations are not captured for a patient (i.e. there are some missing observations that could not be performed or were considered unnecessary by clinicians) an EWS may not be calculated, this may be an exclusion that could introduce bias. This limitation was noted in a recent study looking at the use of EWS for predicting deterioration in the prehospital setting[63].

- Retrospectively looking at observations does not allow for modifications that are built into the NEWS2 system based on patient history – patients with chronic respiratory failure with a lowered SpO2 target may trigger a higher score than they ought if use of an alternate scale is not captured. Likewise, patients with chronic cognitive impairment who should not receive any score for confusion unless it is a change from baseline may receive a high score as this modification cannot be easily applied with retrospective data analysis.
- NEWS2 assigns a high score (3, the highest for any individual observation) to any patient with an acutely altered conscious state. Using this system with conscious state as the predictor variable would be begging the question as a patient with an altered conscious state will be much more likely to trigger any given EWS threshold level.
- NEWS2 is validated for adults, there would need to be an alternate system for children (I am not aware of any paediatric EWS system that has been validated for the prehospital environment) or exclude this cohort from analysis.

6.2.3. Inclusion and exclusion criteria

Cases were included where:

1. The case was within the 12-month period of 27 November 2017 to 26 November 2018. This was the same period (i.e. used the same data set) as the study in Chapter 5.
2. The case involved a response to an emergency call that used MPDS (as opposed to an interhospital transfer or other tasking that was not a call for help in the community).
3. The case was within the Perth metropolitan area. As per the study in Chapter 5, this allowed a single scope of practice (paramedic) which limits potential unintended bias (for example, a case not being marked as high acuity because a volunteer could not perform an intervention that would have been performed had the case been attended by paramedics) along with being more generalisable to other metropolitan areas.

Cases were excluded where:

1. An ePCR was not completed. This would cover events such as calls cancelled prior to arrival.

2. The patient's initial presenting conscious state was not recorded.

As there was no use of dispatch information in this study, there was no need for the exclusions around particular MPDS codes that featured in the previous study.

6.2.4. Analysis

Initial conscious state on paramedic arrival was analysed as a predictor of high acuity patients. Initially, the proportion of high acuity patients at each individual level of consciousness (Alert, Confused, Drowsy, Voice Response, Pain Response, Unresponsive) was calculated. Subsequent to this, I used each level of consciousness as a threshold level (i.e. for each level as a threshold, the numbers would include patients with that level of consciousness *and below*). As described in the methodological overview in Chapter 3, the below measured of diagnostic accuracy were calculated using each level of consciousness as a threshold:

- **Sensitivity:** proportion of high acuity patients who presented with a conscious state at or below the selected threshold level.
- **Specificity:** proportion of lower acuity patients who did not have a conscious state at or below the selected threshold level.
- **Positive Predictive Value (PPV):** proportion of patients with a conscious state at or below the selected threshold level who were high acuity.
- **Negative Predictive Value (NPV):** proportion of patients without a conscious state at or below the selected threshold level who were lower acuity.

The calculation of these measures is illustrated in Figure 6 (Chapter 3).

My rationale for using each level of consciousness as a threshold level rather than treating each individually, is that I want this to be informative for telephone triage. Rather than working out which of the six levels a patient would be at, primary telephone triage aims to be as rapid as possible, therefore being able to find the clinically significant threshold level and then create a question that targets this level and below, may be more useful.

I graphed the overall proportion of high acuity patients (i.e. the positive predictive value) at each threshold level to demonstrate if there was a particular point at which the PPV had a significant rise that may indicate an appropriate threshold level to use for conscious state questioning.

I completed the above analysis on the data set as a whole, and then stratified by each individual case's MPDS code as there may be significant differences with different types of patient presentations.

For the final part of this analysis, I wanted to determine how predictive conscious state is of patient acuity. I constructed a Receiver Operating Characteristics (ROC) curve, measuring the AUC for the whole data set and then again stratified by each individual MPDS protocol for the individual cases. I ranked the AUC for each MPDS protocol to demonstrate which protocols (or types of patient presentations) conscious state is most predictive of acuity.

6.3. Manuscript

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Research paper

Association between initial presenting level of consciousness and patient acuity – A potential application for secondary triage in emergency ambulance calls

Jason Belcher [a,b,*], Judith Finn [a,b], Austin Whiteside [a,b], Stephen Ball [a,b]

[a] *Prehospital, Resuscitation and Emergency Care Research Unit, School of Nursing, Curtin University, Perth, Western Australia, Australia*
[b] *St John Western Australia, Australia*

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ABSTRACT

Introduction: Conscious state assessment is important for the triage of emergency patients. In this study, we measured the association between ambulance patients' conscious state and high versus lower acuity, with a view to informing telephone triage assessment of conscious state.
Methods: Data were analysed from one year of emergency ambulance incidents in Perth, Western Australia. Patient conscious state at the time of paramedic arrival was compared to acuity (based on paramedic assessment and management). We determined the proportion of high-acuity patients across six levels of consciousness (Alert, Confused, Drowsy, Voice Response, Pain Response, Unresponsive) overall, and within individual protocols of the Medical Priority Dispatch System (MPDS).
Results: The proportion of high acuity patients increased with each step across the consciousness scale. Applying conscious state as a binary predictor of acuity, the largest increases occurred moving the threshold from Alert to Confused (22.0–48.6% high acuity) and Drowsy to Voice Response (61.9–89.5% high acuity). The Area Under the Curve (AUC) of the Receiver Operating Characteristic was 0.65. Within individual protocols, the highest AUC was in Cardiac Arrest (0.89), Overdose/Poisoning (0.81), Unknown Problem (0.76), Diabetic Problem, (0.74) and Convulsions/Fitting (0.73); and lowest in Heart problems (0.55), Abdominal Pain (0.55), Breathing Problems (0.55), Back Pain (0.53), and Chest Pain (0.52).
Conclusion: Based on these proportions of high acuity patients, it is reasonable to consider patients with any altered conscious state a high priority. The value of conscious state assessment for predicting acuity varies markedly between MPDS protocols. These findings could help inform secondary triage of ambulance patients during the emergency call.

1. Introduction

During emergency ambulance calls, one of the most important responsibilities of the emergency medical dispatcher (EMD) is to determine the nature and urgency of the patient's presenting condition. Inaccuracies in this triage process can lead to under-triage. This carries potential clinical risk to the individual patient as the response priority may be lower than required. Conversely, over-triage can lead to system-wide risk when patients receive a higher priority than necessary, and resources become unavailable for higher acuity patients [1–4]. Widespread inaccuracies in initial telephone triage have been demonstrated in the literature [5–12].

A key area of questioning in emergency ambulance telephone triage is around the patient's conscious state. It is well recognised that altered conscious states can be symptomatic of a range of high acuity conditions – e.g. stroke [13], head trauma [14], hypoglycaemia [15] and poisoning [16]. Altered conscious states are an essential triage criterion in the Australasian Triage Scale [17], international triage algorithms such as the Manchester Triage System [18], and advanced trauma life support protocols [14]. Many ambulance services worldwide use the Medical Priority Dispatch System (MPDS) [19] for primary triage of emergency ambulance calls. This is a validated scripted system designed to be operated by a non-clinician Emergency Medical Dispatcher (EMD) and rapidly arrive at a triage outcome. Each patient is initially classified into one of 32 protocols that represent the broad nature

* Correspondence to: Prehospital, Resuscitation and Emergency Care Research Unit, School of Nursing, Curtin University, GPO Box U1987, Perth 6845, Western Australia, Australia.
E-mail address: jason.belcher@postgrad.curtin.edu.au (J. Belcher).

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of their medical emergency (e.g. Chest Pain, Diabetic Problem), with subsequent questions, specific to each protocol, assigning the patient a specific dispatch code (known as a determinant) that provides the basis for ambulance prioritisation. In nearly all 32 protocols, determination of patient alertness (via the scripted question 'Is she/he completely alert?') acts as a major determinant of triage, with not-alert patients typically ranking highest (or very highly) for dispatch prioritisation [19].

Our previous study [6] demonstrated that only 6% of ambulance patients who were classified as not alert in ambulance dispatch were also classified as not alert by paramedics upon arrival on scene (i.e. positive predictive value of 0.06). Conversely, we found that 30% of patients who were recorded as not alert on paramedic arrival were dispatched as alert (i.e. sensitivity of 0.70). Notwithstanding the possibility of changes to patient conscious state between ambulance dispatch and paramedic arrival, these results point to major challenges in the alignment of what callers, call-takers, and paramedics classify as an alert, versus not-alert patient. This raises the question as to whether an alternative threshold of patient conscious state (different to the Alert versus Not Alert threshold used by the MPDS) could be more reliably determined, and applied as an indicator of patient acuity during dispatch. Even if not used in primary dispatch protocols, alternative thresholds of conscious state could help inform secondary triage processes (i.e., follow-up conversations with the emergency caller, to further determine the patient's needs for emergency care). However, in the context of dispatch systems generally being risk-averse in relation to patient acuity, it is important to understand how patient acuity varies in relation to alternative levels of patient conscious state. In this study, we sought to (1) characterise this relationship between conscious state and acuity, (2) determine whether a particular threshold of patient conscious state (Confused, Drowsy, Voice Response, Pain Response, Unresponsive) acts as an predictor of patient acuity in the prehospital setting, and (3) determine whether there are types of patients (i.e. reasons for the emergency call) for which the patient's conscious state has good predictive value for their acuity. It is hoped these findings can further inform triage and prioritisation of ambulance resources.

2. Methods

2.1. Setting

This was a population-based observational study of the association between the patient's presenting level of consciousness on arrival of paramedics and their acuity based on paramedic assessment and management, stratified by MPDS protocol. The setting was the metropolitan area of Perth, Western Australia (population 2.06 million in 2018) [20], where St John Western Australia (SJWA) is the sole provider of emergency ambulance services. All ambulance crews include a career Registered Paramedic. The study was based on data for the 12 months from 27 November 2017–26 November 2018.

2.2. Determination of conscious state

SJWA paramedics complete an electronic patient care record (ePCR) for each patient they attend. Conscious state for this study was taken from a data field in the ePCR where the patient's conscious state is recorded by paramedics on arrival. There are six options – Alert, Confused, Drowsy, Voice Response, Pain Response, Unresponsive – a combination of the AVPU (Alert, Voice Response, Pain Response, Unresponsive), and ACDU (Alert, Confused, Drowsy, Unresponsive) scales [21].

2.3. Determination of high acuity patients

A high-acuity filter was created in 2019 by St John WA as part of a review of dispatch priorities, to categorise patients as high acuity or lower acuity. The derivation of this binary categorisation (high acuity vs lower acuity) was based on a process used by Ambulance Victoria, [1] using data on medications administered, interventions performed, patient assessment and patient observations, as determined from the ePCR across the period of paramedic care of the patient (Appendix 1). Each patient was classified as high acuity if they had one or more of the component high-acuity flags (medications, interventions, assessment, observations); else they were classified as lower acuity. For the purposes of simplicity in this study, "lower acuity" refers to a patient who did not meet the high acuity filter, suggesting they did not require time critical prehospital care.

It is important to note that the high acuity filter does include indictors based on paramedic observations of patient conscious state, as measured by the Glasgow Coma Scale (GCS) [22] (see Appendix 1). Specifically, patients were classified as high acuity if they had a total GCS less than 10, or a GCS Motor Response score less than 4, or a GCS Verbal Response Score less than 3 on recorded observations. Thus, there may be some patients in our analysis whose status as both (a) altered conscious state (on the ACDU/AVPU scale) and (b) high acuity is due to GCS values. However, this is in the context of 76 other variables also contributing to the high acuity filter (Appendix 1) - i.e. there are many other ways for patients to be both altered conscious state and high acuity.

2.4. Patients included

Cases were included for analysis if they involved an emergency ambulance call for help in the community (i.e., excluding inter-facility transfers) and the responding paramedic completed an ePCR for the patient. Calls were excluded where conscious state was not recorded on the ePCR.

2.5. Analysis

Initial conscious state (on paramedic arrival) was analysed as a predictor of high acuity patients. Case data with identifiers removed and replaced by a code was imported into MySQL Community Edition version 8.0 (Oracle Corporation, Redwood Shores, California USA) to prepare summary data (case counts by MPDS protocol, conscious state and acuity), and further analysed to produce measures of diagnostic accuracy, ROC curves and AUC using Microsoft Excel 365 (Microsoft Corporation, Redmond, Washington USA).

Initially, the proportion of high acuity patients at each individual conscious state (Alert, Confused, Drowsy, Voice Response, Pain Response, Unresponsive) was calculated and graphed, both overall and for each MPDS protocol. Subsequent to this, conscious states were used as threshold levels, whereby patients were classified as either exceeding a nominated threshold level, or as having the threshold level of consciousness or lower. For example, using the threshold of Drowsy, we classified patients as either being more conscious than Drowsy, or as having a consciousness of Drowsy or less conscious. Using this approach, we treated consciousness as a binary predictor of patient acuity, with the following measures of diagnostic accuracy calculated for different threshold levels:

- Sensitivity (proportion of high acuity patients who presented with a conscious state at or below the selected threshold level)
- Specificity (proportion of lower acuity patients who have a conscious state exceeding the selected threshold level)
- Positive Predictive Value (PPV) (proportion of patients with a conscious state at or below the selected threshold level who were high acuity)

		Patient acuity		
		High Acuity	Lower Acuity	
Patient conscious state	At or below threshold level	True Positive (TP)	False Positive (FP)	Positive Predictive Value (PPV) = TP/(TP + FP)
	Above threshold level	False Negative (FN)	True Negative (TN)	Negative Predictive Value (NPV) = FN/(FN + TN)
		Sensitivity = TP/(TP + FN)	Specificity = TN/(FP + TN)	

Fig. 1. Measures of diagnostic accuracy as used in this study.

- Negative Predictive Value (NPV) (proportion of patients with a conscious state exceeding the selected threshold level who were lower acuity)

The calculation of these measures is illustrated in Fig. 1. This calculation was performed first across the whole data set, then stratified by MPDS protocol. The positive predictive value was graphed overall to demonstrate if there was a particular point at which the PPV had a large increase that may indicate an appropriate threshold level to use for conscious state questioning. Receiver operating characteristic (ROC) curves were produced overall and stratified by protocol to determine the performance of conscious state as a discriminator of acuity for different conditions, measured using the area under the curve (AUC). As the predictor (conscious state) in this case is categorical, an interpolation method [23] was used to calculate AUC. MPDS protocols were excluded from the comparative analysis if they had fewer than 30 patients with a conscious state below (less conscious than) Alert.

2.6. Ethics

Approval for the study was granted by the Curtin University Human Research Ethics Committee as a sub-study of the Western Australian Pre-hospital Care Record Linkage Project (HR128/2013–46), and by the SJWA Research Governance Committee.

3. Results

Of 147,329 patients attended as a result of an ambulance call to SJWA in the time period, 129,192 met the study inclusion criteria (87.69%). The remaining 18,137 were excluded due to no initial conscious state being recorded. Of the included patients, 106,671 (82.57%) were classified as Alert by paramedics on arrival at scene, 8411 (6.51%) as Confused, 7320 (5.67%) Drowsy, 1248 (0.97%) Voice Response, 2040 (1.58%) Pain Response, and 3502 (2.71%) Unresponsive. A total of 28,465 patients (22.03%) of included patients overall were considered high acuity. The proportion of high acuity patients classified as Alert was 16.42%, Confused 26.38%, Drowsy 36.30%, Voice Response 71.39%, Pain Response 85.00% and Unresponsive 98.60% (Fig. 2).

When using each level of consciousness as a threshold level, the sensitivity, specificity, PPV and NPV at each threshold overall are shown in Table 1.

The proportion of high acuity patients at each threshold level (i.e., the PPV) is shown in Fig. 3. The largest rise in the PPV was from using Drowsy as the threshold, to using Voice Response as the threshold level.

The AUC for the whole dataset was 0.649, demonstrating that conscious state alone is a moderate predictor of patient acuity. A ROC for the whole dataset is shown at Fig. 4.

The following 10 MPDS protocols were excluded from comparative analysis because they had fewer than 30 patients with conscious states other than Alert: Animal bites/attacks, Burns/Explosion, Carbon monoxide/inhalation/HAZMAT, Drowning/Diving/SCUBA accident, Electrocution/Lightning, Eye problems/injuries, Heat/Cold exposure, Inaccessible incident/Other entrapments (non-vehicle), Pregnancy/Childbirth/Miscarriage, and Stab/Gunshot/Penetrating trauma.

There were marked differences between the AUC values of different MPDS protocols (Table 2), with the highest values for Cardiac arrest (0.893), Overdose/poisoning (0.812), Unknown problem (0.760), Diabetic problem (0.740) and Convulsion/fitting (0.727). The lowest AUC values were for Chest pain (0.524), Back pain (0.532), Breathing problems (0.549), Abdominal pain (0.551) and Heart Problems (0.554).

The proportion of high acuity patients at each conscious state, and measures of diagnostic accuracy for individual MPDS protocols are shown in Appendices 2–5.

4. Discussion

The initial motivation for our study was to determine whether there is a threshold level of patient conscious state that is more predictive of patient acuity than the distinction between Alert and Not Alert patients, which is the threshold used the Medical Priority Dispatch System (MPDS). Instead, we found a consistent relationship between patient conscious state and acuity, with the proportion of high acuity patients increasing monotonically with each decrement in conscious state. Significantly, one of the largest increases in the proportion of high-acuity patients was between Alert and Confused, 16% – 26%.

Thus, our results suggest that anything other than alert should be treated as a priority. When we analysed each conscious state as a threshold binary predictor, the rate of high acuity patients at the Confused threshold or less (i.e. any altered conscious state), at 49%, is nearly double the benchmark set for automatic high priority dispatch (lights-and-sirens) proposed by Andrew et al. [1]. Significantly, this supports the approach used by MPDS, where the question, "is [the patient] completely alert?" [19], targets this threshold of any altered conscious state. Furthermore, this threshold is also consistent with other assessment systems used in the prehospital environment – for example the NEWS2 score [24], an observation-based early warning score and escalation system which has been validated for prehospital care [25], applies a high score to *any* acutely altered conscious state.

In addition to our results supporting the approach of treating any conscious state as a basis for a priority ambulance response, we also found a large jump in patient acuity between Drowsy and Voice Response, with 89% high acuity among patients who were Voice Response or lower consciousness. Thus, if patients in this exceptionally high acuity group could be identified during emergency

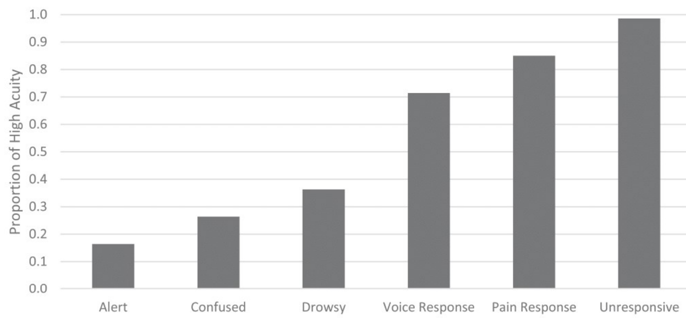

Fig. 2. Proportion of High Acuity patients by level of consciousness.

calls, there may be an ability to provide a modified response to them in some settings - for example, co-response of Intensive Care Paramedics or Critical Care Paramedics in the several Australasian ambulance services who have a response model where these responders are dispatched to likely high acuity patients. Identification of this group could be considered in future development of primary triage systems, and where these patients are identified in secondary triage services discussed below, this knowledge can be used to inform dispatch decisions by clinicians.

Our results highlight that initial conscious state is only a partial predictor of patient acuity. This is evident in our finding of 16% high acuity among patients classified by paramedics as Alert, along with the Area Under the Curve (AUC) of the Receiver Operating Characteristic for the overall cohort of ambulance patients being only 0.65. This is not a surprising finding, and it makes intuitive sense that there would be other factors that would make a patient high acuity without an altered conscious state, for example difficulty breathing or high mechanism trauma. While the predictive value of conscious state alone for the whole patient cohort was modest at best, there may be some presenting conditions for which a patient's conscious state is more predictive of their acuity.

At the start of this study, we proposed that the relationship between conscious state and acuity could vary between MPDS protocols – i.e., that conscious state may be more tightly linked with acuity for some medical conditions or incident types than for others. Stratifying the analysis by protocol at the time of dispatch, we found this was the case. Using the AUC to summarise the predictive performance of conscious state in relation to patient acuity, the five protocols with the highest AUC (exceeding 0.72) were Cardiac or respiratory arrest/death, Overdose/Poisoning, Unknown problem, Diabetic problems, and Convulsions/Fitting. These results would indicate that conscious state has good predictive value for patient acuity in these protocols. At the other extreme, the five protocols with the lowest AUC were Heart problems, Abdominal pain/problems, Breathing problems, Back pain, and Chest pain. The AUC for these five protocols was lower than 0.56, approaching the level of a random predictor, of 0.50. Thus, we would conclude that conscious state was a poor discriminator of acuity for these patients. These results could be used to prioritise conscious state assessment in secondary triage of these emergency calls.

With increasing demand on health and ambulance systems [26], many ambulance services are conducting secondary triage on lower priority responses [3,27–29] to (1) conduct a better clinical assessment of the patient and ensure high acuity conditions have not been missed in primary triage, and (2) refer appropriate patients to alternative care pathways other than ambulance and Emergency Department (ED) attendance. Secondary triage services may also conduct call-backs to higher priority patients who are likely to wait an extended period of time, in the form of welfare checks and conducting further clinical assessment. These secondary triage services are frequently multidisciplinary, with several Australasian jurisdictional ambulance services employing Registered Nurses and Paramedics as secondary triage clinicians [27,29]. Unlike primary triage which attempts to conduct a rapid assessment to get to a dispatch priority outcome as quickly as possible, clinician-led secondary triage has more time to conduct a detailed assessment, as the call has either already had an initial dispatch priority allocated or has been deemed to be non-urgent so can wait for secondary triage prior to dispatch.

In our previous study [6] on the predictive accuracy of dispatch determination of patient conscious, we found that only 70% of Not Alert patients (as determined by paramedics on scene arrival) were classified as Not Alert during dispatch (i.e., 70% sensitivity). In relation to under-triage of altered conscious state during dispatch, secondary triage services may provide an important safety net, with the ability to ask more detailed questions concerning consciousness. Conversely, there may also be value in further questioning in relation to patients who were coded as Not Alert but had no other high acuity indicators.

The results of our study may help inform how well conscious state may help secondary triage for different protocols. Among the protocols where conscious state was most highly predictive of acuity (i.e. the highest AUC), we propose that the most promising potential application for secondary triage is for Overdose/Poisoning, Diabetic Problems and Convulsions/Fitting. An understanding of the patient's level of consciousness in secondary triage may have significant value

Table 1
Measures of diagnostic accuracy.

Threshold level	Alert	Confused	Drowsy	Voice Response	Pain Response	Unresponsive
Sensitivity	1.000	0.385	0.307	0.213	0.182	0.121
Specificity	0.000	0.885	0.947	0.993	0.996	0.999
PPV	0.220	0.486	0.619	0.895	0.936	0.986
NPV	N/A	0.164	0.171	0.183	0.188	0.199

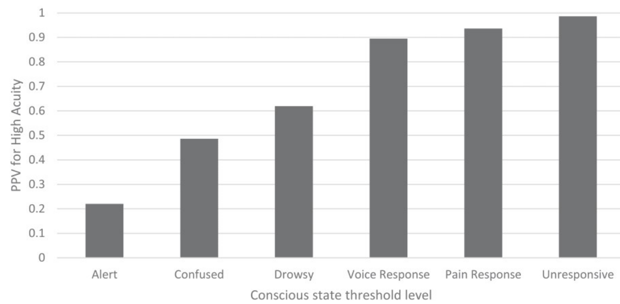

Fig. 3. Proportion of high acuity patients (i.e. PPV) at each threshold level of conscious state.

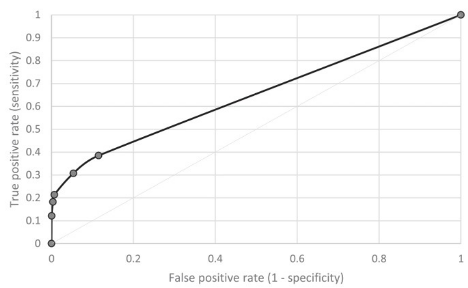

Fig. 4. Receiver Operating Characteristic curve for all included patients.

Table 2
Area Under the Curve for specific MPDS protocols.

MPDS Protocol	AUC
09 Cardiac or respiratory arrest/death	0.893
23 Overdose/Poisoning (ingestion)	0.812
32 Unknown problem	0.760
13 Diabetic problems	0.740
12 Convulsions/Fitting	0.727
31 Unconscious/Fainting (near)	0.693
04 Assault/Sexual assault	0.693
28 Stroke (cerebrovascular accident)	0.673
29 Traffic/Transportation incidents	0.650
25 Psychiatric/Abnormal behaviour/Suicide attempt	0.645
11 Choking	0.626
26 Sick person (specific diagnosis)	0.625
30 Traumatic injuries (specific)	0.602
21 Haemorrhage/Lacerations	0.590
17 Falls	0.588
18 Headache	0.581
02 Allergies (reactions)/Envenomations (stings, bites)	0.579
19 Heart problems	0.554
01 Abdominal pain/problems	0.551
06 Breathing problems	0.549
05 Back pain (non-traumatic/non-recent trauma)	0.532
10 Chest pain (non-traumatic)	0.524

in these cases, in combination with other clinical indicators. Convulsions/Fitting is particularly notable, as the MPDS does not presently ask about conscious state in this protocol, [19] whereas our analysis shows conscious state to be a reasonable discriminator of acuity. This may be related to the temporal nature of the initial emergency call when the patient may be more likely to be actively seizing or at the beginning of a post ictal phase. It does not predict how they will present after resolution the seizure, whereas a patient who still has an altered conscious state on arrival of paramedics is more likely to be high acuity.

While conscious state was also highly predictive of acuity for patients dispatched as Cardiac Arrest, we propose secondary triage is not applicable for such patients, due to the emphasis set on Telephone CPR [30] (i.e. if classified as cardiac arrest in the emergency call, it is far more important to pursue CPR than re-assess consciousness). In addition, the critical nature of cardiac arrest means that the call-taker is likely to remain on the call until paramedics arrive, so that if there are changes in patient condition (including consciousness), those changes can be detected by the call-taker, rather than requiring a separate secondary triage process. For patients classified as Unknown Problem, the practicalities of secondary triage are limited by the fact that this protocol typically relates to situations when a third party has called for an ambulance (i.e., when the caller is not on scene with the patient, and therefore with little ability to further determine patient status).

There are also protocols for which we propose there is likely to be reduced value in pursuing detailed conscious state assessment as part of secondary triage: notably, Heart problems, Abdominal pain/problems, Breathing problems, Back pain, and Chest pain, due to the low predictive performance (i.e. low AUC) we observed. This is not to say that such protocols should be excluded from secondary triage altogether, or that any changes in conscious state that become evident in the secondary triage of such patients (or in the initial call) should be overlooked. Rather, our recommendation is that information on conscious state should not be pursued as a priority in secondary triage for such patients, and that efforts focus on identifying other, more informative clinical discriminators of patient acuity.

While this study focussed on altered conscious state as a predictor, the same methodology could be applied to other predictors, such as abnormal breathing – i.e. to identify how the degree of abnormal breathing is associated with acuity, and to identify different patient presentations where abnormal breathing has the greatest predictive value in relation to patient acuity, and thus in what presentations assessment of this should be prioritised in secondary triage.

5. Limitations

The definition of high acuity patients in this study is based on a bespoke St John WA filter using paramedic recorded prehospital assessment and management. This methodology as first described by Andrew et al. [1] has been accepted into practice for prioritisation of ambulance calls, and there was broad consensus amongst the review panel who developed the SJWA high acuity filter (including internal paramedic clinicians, emergency physicians, academics and community representation). There has been some level of validation against an internal subjective assessment of acuity based on the attending paramedic, however there has been no external validation into the robustness of the SJWA high acuity filter.

Overall, 18,137 patients (12.3%) were excluded from analysis due to no initial conscious state being recorded on paramedic attendance. It is unclear whether there is any pattern in the types of patients where this was not recorded, and thus whether this may have introduced a selection bias that may modify the results.

6. Conclusion

Our analysis found no single threshold for presenting conscious state as a predictor of high acuity patients. Instead, there appear to be two distinct change points: between Alert and any altered conscious state; and between Drowsy (or better) and Voice Response (or worse). Based on our findings it would be reasonable to consider any patient with any acutely altered conscious state a high priority, which aligns with the wording of the alertness question in MPDS.

We found that conscious state was a good predictor of high acuity patients for patients in the Overdose/Poisoning, Diabetic Problems and Convulsions/Fitting protocols. We suggest that any secondary triage efforts for these patient groups should aim for further certainty about patient conscious state (including possible changes in conscious state prior to paramedic arrival). Conversely, we found conscious state to be a weak predictor of acuity in other complaints, including Chest Pain, Back Pain, Breathing Problems and Abdominal Pain. We suggest that any secondary triage efforts in these patient groups should be focused on other pertinent factors relating to these complaints over conscious state assessment.

Competing Interests

The authors declare no competing interests. Each author of this paper has completed the ICMJE conflict of interest statement. JB and AW are employed full time by SJWA as Clinical Quality Manager and Operations Manager respectively. JF receives partial research funding from SJWA, and both JF and SB have adjunct research appointments with SJWA.

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Supporting information

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.auec.2022.11.002.

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Supplementary data referred to as Appendix 1-5 in this manuscript are reproduced in Appendices 4-8 respectively at the end of this thesis.

6.4. Summary

This study was a retrospective analysis which measured the association between a patient's presenting conscious state on arrival of paramedics, and their acuity. The aims of the analysis were to characterise the relationship between conscious state and acuity, determine if there was a particular threshold level that could be targeted in dispatch due to its association with a high rate of high acuity patients, and determine types of patient presentations for which conscious state holds the best predictive value of acuity.

I found a monotonic relationship between patient presenting conscious state and acuity, with the rates of high acuity patients increasing with each step across the descriptive spectrum (Alert, Confused, Drowsy, Voice Response, Pain Response, Unresponsive). When applying a threshold approach, I found that nearly half of all patients with any conscious state other than Alert (i.e. Confused or worse) were high acuity (48.6%), compared to 16.4% of patients who were Alert and 22.0% of the whole data set (i.e. overall prevalence). Furthermore, there was a large rise in the rate of high acuity patients between threshold levels of Drowsy (61.9%) and Voice Response (89.5%). With the extremely high rate of high acuity patients with a conscious state of Voice Response or lower, there may be opportunity for triage systems to have a second threshold at this level. Given the magnitude of the rise in the rates of high acuity patients from Alert to Confused or lower, it is reasonable to conclude that any altered conscious state should be treated as a priority. With nearly 9 in 10 patients with a conscious state of Voice Response or lower being high acuity, triage systems could potentially also use this as an informative threshold for dispatch response.

In terms of patient presentations where conscious state held a high predictive value for acuity, I found high predictive values for patients on the Overdose/Poisoning, Diabetic Problems and Convulsions/Fitting protocols of the MPDS. Conversely, conscious state showed the lowest predictive value for acuity for patients on the Chest Pain, Back Pain, Breathing Problems and Abdominal Pain protocols.

Recommendations arising from these findings are detailed in the discussion in Chapter 7.

Chapter 7. Discussion

The original purpose of this research was to understand the accuracy of assessment of patient conscious state in the setting of emergency ambulance calls; and to gain an understanding of appropriate levels of conscious states to target in dispatch triage prioritisation. This research was performed in the setting of Perth, Western Australia, where the jurisdictional ambulance service is provided by St John Western Australia. I begin my discussion by summarising the key findings from my research outputs, followed by discussion of the strengths and limitations of my research in this project. I then present recommendations including directions for further research and review of clinical practice; and finally propose ways in which this research could be translated into practice.

7.1. Key findings

7.1.1. Systematic Review

Aim 1: To understand the current literature surrounding accuracy of conscious state assessment in the setting of ambulance calls, by means of a systematic review.

Determining whether a patient is conscious or not is a key question asked early in telephone triage systems (along with whether the patient is breathing)[12, 13]. The most used primary triage systems worldwide – Medical Priority Dispatch System (MPDS)[12] and Criteria Based Dispatch (CBD)[13] – both ask further questions about conscious state in patients who are initially classified as conscious, to identify altered conscious states.

I conducted a systematic review of research literature comparing a patient's conscious state in emergency calls to findings at the scene. Despite the ubiquitous nature and importance of this questioning, this systematic review found very limited research assessing outcomes of these questions. My initial literature search conducted towards the start of this project found only two relevant articles – one 1995 study[48] describing findings when a call is received for a patient reported to be unconscious, and a 2007 study[47] investigating the accuracy of assessment of conscious versus unconscious in emergency calls.

On 18 July 2022 an updated literature search was conducted to locate any newly published literature in the subject matter. A 2020 study[44] around rescue helicopter dispatch to medical collapses, and findings at scene, was located. The data in a subset of these cases were suitable as they described dispatch based on the patient being reported as unconscious on the initial telephone call. This search also located a paper[37] published as part of my MPhil research, assessing accuracy of conscious state assessment in patients reported as conscious on an emergency call.

Results on accuracy of conscious state assessment in the initial telephone call varied between the studies, and due to clinical heterogeneity no meta-analysis was conducted. The small number of studies and small numbers of patients involved in those studies shows that this is an under-researched area.

7.1.2. Accuracy of call-taker assessment of conscious state

Aim 2: To measure the accuracy of call-taker assessment of conscious state in the Western Australian ambulance service by comparing the reported conscious state in the emergency call to the conscious state recorded on arrival of paramedics.

Having identified a knowledge gap in the published literature, I undertook a study into the accuracy of call-taker assessment of patient conscious state. This study compared patient conscious state as recorded during the emergency call to the conscious state found on assessment by paramedics on arrival at the scene; and included 109,678 patients reported as conscious in the emergency call, over a 1-year time period (27 November 2017 to 26 November 2018).

The results showed a high level of over-triage, with more than 10 times as many cases dispatched as “not alert” than the number of patients found to have an altered conscious state. The positive predictive value was only 6.6%. Despite the appearance of a risk averse system, the sensitivity was only 70%. Thus, even with the high rate of over-triage, 3 in 10 patients found to have an altered conscious state on arrival of paramedics were not recognised as such by the call-taker.

The primary analysis for this study used the 'AVPU' (Alert, Voice Response, Pain Response, Unresponsive) scale in relation to paramedics' determination of patient conscious state. I also conducted an alternative analysis where I treated any deviation from completely alert (including drowsy and confused) as an altered conscious state. Using this definition, the positive predictive value was markedly increased to 34% -however the sensitivity was 47% - meaning that more than half of altered conscious states were not detected. The results indicate that regardless of the definition, there is poor accuracy in both directions in telephone assessment of conscious state in primary triage – both over-triage and under-triage.

Accuracy varied between MPDS protocols (broad reasons for the call), with conditions where an altered conscious state is a more likely expected symptom (such as diabetic problems, overdose/poisoning, stroke and unconscious/fainting) demonstrating higher positive predictive values than other protocols.

7.1.3. Association between conscious state and patient acuity, and identification of presenting conditions with high predictive value of acuity

Aim 3: To measure the association between the patient's presenting conscious state (as assessed by the paramedics on arrival at the scene) and the patient's acuity. To use this information to identify types of calls (presenting complaints) that may most benefit from a more thorough assessment of conscious state, and thereby inform emergency telephone triage.

In relation to the ambiguities in the way that ambulance dispatch systems could classify patient alertness, I conducted a further study to measure the association between a patient's presenting conscious state and their acuity, with a view to finding an appropriate threshold level. This study included 129,192 patients during the same 1-year (27 November 2017 to 26 November 2018) time period as the previous study and compared the patient's conscious state as assessed by paramedics on arrival on scene, with an indicator of whether or not they were high acuity based on paramedic assessment and management.

Overall, there was a consistent (monotonic) relationship between patient conscious state and acuity. The proportion of high acuity patients increased with each decrement in conscious state.

The largest increases in the proportion of high-acuity patients were between Alert and Confused, and between Drowsy and Voice Response.

My findings suggest that the most appropriate approach to classifying altered conscious state in the context of emergency ambulance calls is to make the distinction between completely alert patients, and those with any change in conscious state. Almost half (49%) of the patients at the level of Confused or lower (i.e. any conscious state other than “Alert”) had high acuity presentations, compared with 16% of Alert patients (i.e. above this threshold). This rate is almost double the 25% threshold level for ambulance dispatch under priority conditions proposed by Andrew et al(9) in their methodology. This is consistent with the wording of the question used in MPDS – “is [the patient] completely alert?”(12) which also appears to target any altered conscious state.

There was also a large rise in the rate of high acuity patients at the level of Voice Response– with 89.5% patients at this level or below having a high acuity presentation. Primary triage systems do not currently target this level of consciousness. However the extremely high proportion of patients with high acuity presentations at or below this level could give rise to consideration for another threshold for a specialised response in ambulance triage and dispatch systems.

Along with examining the relationship between presenting conscious state and patient acuity, I sought to assess the utility of using a patient’s conscious state to ascertain their likelihood of being a high acuity patient. I measured this using the Area Under the Curve (AUC) of a Receiver Operating Characteristics (ROC) curve, measuring conscious state as a predictor of acuity.

Overall, I found that initial conscious state alone was only a partial predictor of acuity, with an AUC of 0.65. This is not a surprising finding given there may be many other factors that could result in the patient’s clinical condition being deemed ‘high acuity’ – for example respiratory distress or major trauma. However, there were a wide range of values when stratifying the results by MPDS protocol. Conscious state could be shown to be a reasonable predictor of patient acuity in Cardiac Arrest Overdose/poisoning, Unknown problem, Diabetic problems, and Convulsions/fitting. Conversely, conscious state was shown to be a poor predictor of acuity in Chest Pain (traumatic), Back pain, Breathing problems, Abdominal pain and Heart problems.

7.1.4. Summary

As discussed in the methodology chapter, this research sought to explore the relationship between three concepts, namely: (1) conscious state determination during the emergency call, (2) patient actual conscious state on arrival of paramedics, and (3) patient actual acuity. I identified that attempting to predict patient acuity based on conscious state assessment during an emergency call is premised on (a) accuracy of telephone assessment as a predictor of patient actual conscious state, and (b) patient conscious state as a predictor of acuity.

In these terms, the second level of prediction – patient conscious state as a predictor of acuity - is demonstrated to have reasonable predictive value. While this can vary based on the patient's presenting complaint, the data suggests it is reasonable to treat any patient with an altered conscious state as a priority. On the other hand, the first level of prediction – telephone triage assessment as a predictor of patient conscious state as determined by paramedics – was shown to have poor accuracy, with high rates of both false positives and false negatives.

These findings support the apparent intention of the approach used in the MPDS – with the question asked appearing to be looking for any altered conscious state. However, the present wording of the question does not appear to be generating answers that are predictive of the patient's actual condition. Further research and system development should focus on improving this first level of prediction – telephone triage. Suggestions for further research in this area are detailed later in this chapter.

7.2. Strengths and limitations of the research

7.2.1. Strengths

There are three key strengths to my MPhil research. Firstly, as identified in the systematic review, this is the first research published in peer-reviewed journals considering identification of altered conscious states in conscious patients during telephone triage of emergency calls. This is despite the inaccuracies overall in telephone triage previously identified in the literature[1-8], and the fact that most callers to ambulance services using the two most commonly used primary triage algorithms are asked about a patient's conscious state[12, 13].

Secondly, as my studies applied across all emergency ambulance presentations (rather than a specific subset of circumstances), they have broad application, and benefitted from large sample sizes – with 109,678 patient presentations; whereas the next largest sample size in a study reported in my systematic review only had 1,655 patient presentations[47].

Thirdly, the six-level descriptive scale of patient conscious state used by SJWA (Alert, Confused, Drowsy, Voice response, Pain response, Unresponsive) allows a much more precise understanding of a patient's responsiveness on paramedic arrival. This scale combining the descriptors of the AVPU and ACDU scales allows for the ability to note subtle conscious state deterioration along with describing greater neurological dysfunction[36]. Being able to use this full set of descriptors that may align to words used by a caller in an emergency call meant I could gain a more nuanced understanding of the relationship between call-taker assessment, paramedic assessment using these descriptors and patient acuity.

7.2.2. Limitations

I recognise that there are limitations to my research as follows:

Firstly, my studies are based in a single setting – a single ambulance service in a single metropolitan city. There may be characteristics in the environment or particular processes within this service that mean the results are not as generalisable to other systems. St John WA's combined ACDVPU scale for initial recording of patient conscious state, while used in daily clinical use, has not been validated. While I used the data from this scale as it was readily available and aligned to the questions in MPDS, the use of this scale may also limit generalisability of the results found.

Secondly, and related to my study being based on a single location, I recognise that language can have regional variations. When discussing telephone triage and communicating meaning through questions and answers, linguistics is an important consideration. It may be that my findings in Australia, or even specifically the State of Western Australia, are not generalisable to other locations because the results are affected by regional language variations.

Thirdly, assessment of patient acuity was based only on assessment and management in the prehospital environment. While this methodology is accepted in practice, it has not been externally validated against patient outcomes. Ideally, outcome data such as mortality, ICU admission, or final diagnosis would be used for determination of acuity, however this information is not available in the ambulance service data set and would require data linkage beyond the scope of this project. I suggest this would have value for future research in this area.

Finally, when assessing dispatch accuracy in relation to the findings of responders, there is an inevitable time lag between the two assessments. During this time, it is entirely possible for there to have been a deterioration or improvement in the patient's conscious state from their presentation at the time of the emergency call. This may be further confounded by the fact that a patient reported to have a normal conscious state is more likely to be given a lower response priority and thus have a longer response time than a patient reported to have an altered conscious state. Callers are encouraged to call back if there are any changes to the patient's condition between the initial emergency call and arrival of paramedics, at which point the call would be re-triaged and the assessment updated which mitigate some of this limitation, however it is not possible to rely on this. Thus, my studies are couched in terms of the predictive value of the telephone assessment for scene findings, because it is not possible to have a "gold standard" assessment of conscious state at the time of the initial call.

7.3. Recommendations arising

There are a number of implications of my research, and recommendations that arise. These broadly fall into areas for further research, and areas to review clinical practice for potential translation of this research. These can apply to both primary and secondary triage settings. Primary triage with its aim to produce a rapid reproducible outcome to ensure that potentially high acuity patients are identified as quickly as possible, tends to be significantly more structured and protocol-based. Since any practice change would not be a consideration on an individual patient basis but implementing modification to protocols used for all patients, more research is needed to propose any improvements to these systems. I have identified several opportunities for further research below. Conversely, secondary triage services as clinician led systems allow for a much more personalised assessment by a clinician, and thus there are recommendations that can be made for consideration for these services to implement for appropriate patients as identified by clinicians.

7.3.1. Further research opportunities

Arising from this research, the following opportunities have been identified for further research to better understand and improve identification of altered conscious states during triage of emergency ambulance calls.

7.3.1.1. Research in other settings

Firstly, similar research could be repeated in other settings to confirm or challenge generalisability of the findings. As discussed in the limitations, my research was conducted in a single setting - the jurisdictional ambulance service in Western Australia. If any differences are noted in accuracy in other settings, it may be possible to research whether regional variation in language makes a difference in the triage interview process. There would also be value in understanding the relationship between presenting conscious state and acuity in other ambulance services. The High Acuity Filter methodology based on the methodology by Andrew et al[9] used for the study in Chapter 6 is based on expert consensus using data fields available in the documentation system used by St John Western Australia. Repeating this in different settings with different consensus filters based on their available data fields may lead to a better universal consensus on recognition of acuity and alignment of conscious state to acuity.

7.3.1.2. Alternative wording of questions

A second potential topic for further research is in the language of questioning of conscious state assessment by call-takers to emergency callers. Based on my research, I have proposed that an appropriate level of consciousness to target in primary triage is whether the patient has any conscious state alteration. In addition, I provided evidence that the caller responses to current questioning on this criterion is frequently inaccurate. Further research likely sits in the realm of linguistics rather than clinical research – with an aim of ensuring that accurate meaning is communicated in the question-and-answer sequence, as has been conducted in caller-call-taker interactions for cardiac arrest calls[64, 65]. This has previously been identified as an area requiring further study – with the original developer of the MPDS algorithm describing “determining true non-alertness” as one of the “holy grails” requiring further research in emergency call triage[21, 58].

It is worth noting that there is already some research in this area, with studies investigating an alternative question in emergency calls. The MPDS provides the clarifier question "is s/he responding normally?" which can be used where a caller has not understood or been able to answer the primary question, "is s/he completely alert?". Two studies have compared caller understanding of the when the clarifier question was instead used as the primary question – first in a Portuguese-speaking emergency call centre in Brazil(66), then in multiple English-speaking centres in the United States(67). While not identified in my systematic review as they were published in a non-indexed journal and would have not met inclusion criteria for the systematic review as they did not compare any on-scene findings, these studies are informative. The results indicate significantly better caller understanding of the clarifier question than the primary question, and it is not unreasonable to suggest this may lead to more accurate answers.

Another alternative question could be the one asked in Criteria Based Dispatch – "can the patient respond to you and obey simple commands?"(13). In any event, a prospective trial to compare the alignment of the answer to an alternative question to on-scene findings by responders would demonstrate the value of that question for accurately predicting altered conscious states in patients.

During the writing of this thesis after publication of the research studies, a new version of MPDS was announced. The release notes show that this new version has implemented the change noted above, with the current version's primary and clarifier questions being swapped in the new version(68). Thus after implementation, the primary question asked to a caller to determine altered conscious states will be "is s/he responding normally?". This change will enable before-and-after observational studies (such as that in Chapter 5 of this thesis) pre- and post-implementation to determine if there is an impact on accurate recognition of altered conscious states.

7.3.1.3. Acute versus chronic altered conscious states

Tools for face-to-face triage and assessment typically treat altered conscious states differently if they are a new presentation, versus a patient's baseline. For example, when assessing conscious states the Australasian Triage Scale deems a Category 4 (semi-urgent) or 5 (non-urgent) triage score appropriate for patients with their "Normal GCS"(18). The NEWS2 score, as previously discussed, assigns a high score to any acutely altered conscious state, but no score if a patient's conscious state is their baseline (for example, chronic confusion in the case of dementia)[60]. Recognition of patients' baseline conscious states, however, does not appear in most telephone triage questions in emergency dispatch.

In addition to the 32 protocols used for triage of emergency calls in the community, MPDS includes a Protocol 33 (Transfer/Interfacility/Palliative Care) designed for health professional callers. This protocol includes a follow-up question to the "Is s/he completely alert" question, which asks "Is this a sudden or unexpected change in her/his usual condition?"; with a high priority determinant being generated only if the altered conscious state is an acute change[12]. Further research on the accuracy of this questioning, in relation to patient acuity, may indicate whether there would be value in a similar follow-up question being used for all callers. It is worth noting that there is a rule in MPDS Protocol 26 stating that "Patients who are normally not completely awake should be considered alert in the dispatch environment"[12], however there are no questions around this in the protocol so this would have to be volunteered by the caller outside of the question sequence to be considered. There may be obvious practicalities to consider with implementation of adding further questioning around patients usual state to all callers, for example, where the patient is not known to the caller. However, depending on the results of such research there may be potential to reduce over-triage for patients living with a reduced conscious state as their baseline.

7.3.1.4. Assess second threshold level for recognising extremes of acuity

At present, dispatch systems such as Criteria Based Dispatch and the Medical Priority Dispatch System ask whether a patient is conscious towards the beginning of the call, and subsequently (for conscious patients) ask about alertness/responsiveness. This effectively means there is a three-scale conscious state assessment in primary triage – Alert/Not Alert/Unconscious. My study in Chapter 6 identified Voice Response as a potentially useful further threshold in conscious state assessment, due to the very high rate of high acuity patients at this level (89.5%). Adding an additional threshold could, for example, take the form of the delineation between the "Altered level of consciousness" and "Not alert" protocols found on Protocol 26 of MPDS. Ambulance services could use this threshold to differentiate a response if a patient is far more likely to be high acuity – for example an increased level of capability such as Intensive Care Paramedic or Critical Care Paramedic responders.

Primary triage systems currently seek to identify patients who are completely unresponsive. This should remain rather than moving the threshold level to Voice Response, as identification of unresponsive patients is important for recognition of cardiac arrest, requiring the time-critical high priority response.

Further research is required into the value of a separate triage category for patients at a conscious level of Voice Response or lower, including understanding the nature of patients in this category. It may be that there is value in tasking clinicians with an increased scope of practice and experience managing these patients, or it may be that although they are high acuity, they do not require additional resources to manage the patient's condition, and such a change would lead to over-triage. Research across multiple settings would be required to prove value for such a change, after which further research into the linguistics of how to ask a question that rapidly determines a patient has a conscious state of Voice Response or lower would be required.

7.3.1.5. Use same methodology to find other predictors of acuity

While a patient's conscious state is an important part of assessment and a predictor of their acuity, it is only one of many factors that can influence whether they are deemed a high acuity patient for the purpose of ambulance triage. As identified in the manuscript in Chapter 6, there is opportunity to apply the same methodology (measuring the association between an assessment and patient acuity), to other patient assessments where that assessment can be reasonably conducted via telephone triage. If this were repeated for multiple factors it could build a body of knowledge based on prehospital patient presentations that would be useful for triage and risk stratification, particularly in a secondary triage setting.

7.3.2. Potential translation of research into practice

The following recommendations are primarily related to Secondary Triage settings. As described in the manuscript in Chapter 6, secondary triage services are clinician-led services who conduct a more detailed assessment after primary triage to ensure high acuity patients are not missed; and to refer appropriate patients to care pathways other than ambulance and emergency department attendance. Given these services are operated by clinicians and are not limited by the same time constraints and algorithmic nature of primary triage systems, there is more scope for individual assessment and clinical judgement with a given patient. In view of my research, there is opportunity to consider practice changes in the area of re-assessment of patient conscious state.

As discussed previously, I found large inaccuracies demonstrated in conscious state assessment in primary triage. At the threshold level shown to be most clinically appropriate (any altered conscious state), the sensitivity for detection of altered conscious states was 47.2%, while the positive predictive value was 34.1%. This indicates considerable under-triage and over-triage due to conscious state assessment in primary triage. Secondary triage services are well positioned to perform a more detailed assessment of patient's conscious state.

Along with more detailed assessment, secondary triage also has the ability to detect changes in a patient's conscious state since the primary triage. While primary triage is a 'point in time' which will often be close to the time of the event or acute presentation that led to an ambulance being called, secondary triage occurring later allows for changes in the situation (such as a patient having recovered from a syncope) and thus may safely improve triage performance. This may be particularly useful in the context of the MPDS, which does not explicitly (through structured questions) seek to differentiate between syncope during the time of the call and longer-lasting periods of altered conscious states.

I would make the following recommendations for consideration for implementation for practice:

7.3.2.1. Targeted re-assessment of conscious state in relevant protocols

Based on my research in Chapter 6 where I identified MPDS protocols for which a patient's conscious state has a higher predictive value for their acuity, secondary triage conscious state assessment should be emphasised for patients on these protocols. Relevant protocols for this would include:

- Overdose/Poisoning

- Diabetic Problem
- Convulsions/Fitting
- Unconscious/Fainting
- Assault/Sexual assault

From a patient safety perspective, any emergency call that is categorised in these protocols and generates a low priority response from primary triage should be targeted by secondary triage for re-assessment of conscious state, to ensure the patient does not have, or progress into, an altered conscious state. While some of these protocols have high sensitivity for detection of altered conscious states in primary triage (e.g. Diabetic Problem at 90.2%), others are very low (e.g. Assault/Sexual assault at 38.8%). A process for re-assessment of patients on these protocols provides a safety net to prevent under-triage.

7.3.2.2. Treat any altered conscious state as a priority

Based on my findings in the study in Chapter 6 around the predictive nature of level of consciousness for acuity, any altered conscious state identified during the triage process should be treated as a priority. This should, in general, also apply to altered conscious states identified through a secondary triage process. Secondary triage clinicians may have scope to vary this, for example where it is identified that the conscious state is the patient's baseline and not a new presentation. However secondary triage clinicians should be aware that the rate of high acuity patients increases markedly with any altered conscious state. and triage accordingly. Organisational guidelines around secondary triage should reflect this.

Furthermore, secondary triage clinicians should be aware of the very high rate of high acuity presentations for patients with a conscious state of Voice Response or lower (89.5%) and make priority and resource recommendations accordingly, when these patients are identified through a secondary triage process.

7.3.2.3. Review of high priority calls with altered conscious states identified in primary triage

Over-triage of calls can reduce availability of ambulance resources for truly high acuity patients[9, 10, 69]. While secondary triage services typically assess lower priority patients (so as not to delay dispatch of resources to high priority calls), in times of peak demand there can be situations where high priority calls are waiting for dispatch, and there would be opportunity for further triage conversations. With the inaccuracy of determination of patient conscious state using primary triaging questioning demonstrated in my analysis in Chapter 5, there could be a place for secondary triage services to review calls that are given a high priority based on an altered conscious state identified in primary triage.

Secondary triage clinicians have the opportunity to ask multiple questions to understand a patient's conscious state and background as opposed to limited scripted question in a primary triage algorithm. As such it is not unreasonable for a clinician after a full assessment to come to a different conclusion around a patient's conscious state, than the initial rapid primary triage algorithm. Where a clinician has determined the patient does not have an altered conscious state, and there are no other priority symptoms or concerns present that would necessitate a high priority ambulance dispatch, it would not be unreasonable for such a call to be downgraded to a lower priority to address the risk of over-triage.

Any ambulance service implementing such a policy relating to re-assessment of conscious state on calls initially allocated a high priority should have guidelines around these processes. These would include how a comprehensive conscious state assessment should be performed by clinicians, in order to ensure patient safety and that under-triage is not introduced by this process.

7.4. Conclusion

This thesis explored the association between call-taker assessment of a patient's conscious state in an emergency ambulance call and findings by paramedics at the scene in response to that call. It also compared those conscious state findings on arrival at scene to patient acuity. This was all in the context of the ambulance service in Western Australia and specifically metropolitan Perth. I found that a patient with any altered conscious state (as determined by paramedics) was sufficiently predictive of them being high acuity to recommend that any altered conscious state identified on an emergency call be a trigger for a high priority ambulance response – effectively supporting the wording of the question currently used in ambulance triage using the MPDS – "is [the patient] completely alert?". However, there was poor alignment between telephone triage assessment of patient conscious state using this question, and the findings by paramedics. The perception of considerable over-triage was validated, however under-triage was also demonstrated, meaning this is not simply a risk-averse triage approach.

Given the knowledge gap about conscious state assessment in emergency calls demonstrated in the literature, I have suggested further research in this area in other settings to understand the generalisability of the results, and whether the inaccuracy in triage is potentially due to regional variation in language. I have also advocated for further research into the wording of primary triage questions in the hope of identifying a question that yields more accurate triage. I have also raised suggestions for consideration by ambulance services with a secondary triage service, in terms of considering how this service could use clinical experience and decision support tools to conduct a more thorough assessment of patient conscious state to ensure calls are allocated an appropriate response.

Improving triage of patient conscious state in emergency calls, and improving triage accuracy more generally, has the potential to increase patient safety through both ensuring high acuity conditions are not missed in the triage process, and also ensuring patients without a high acuity condition are less likely to receive a high priority response and thus make resources unavailable to others in the community. My hope is that the research conducted in this thesis can inform telephone triage processes in ambulance services, with a view to better utilising limited ambulance resources by reducing over- and under-triage, thereby ensuring that patients with a true altered conscious state receive a priority response, while keeping resources available in the community for the truly high acuity patient.

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Appendix 1:PROSPERO Registration

PROSPERO
International prospective register of systematic reviews

Accuracy of call-taker assessment of patient conscious state, in the setting of telephone calls to an emergency service

Jason Belcher, Stephen Ball, Judith Finn

Citation

Jason Belcher, Stephen Ball, Judith Finn. Accuracy of call-taker assessment of patient conscious state, in the setting of telephone calls to an emergency service. PROSPERO 2019 CRD42019116403 Available from: https://www.crd.york.ac.uk/prospero/display_record.php?ID=CRD42019116403

Review question

How accurate is call-taker assessment of patient conscious state, in the setting of telephone calls to an emergency service (e.g. an ambulance service), compared to findings by first responders at scene?

Searches

Databases: Ovid All Journals, MEDLINE, Embase. No restrictions on date. Searching for concepts of pre-hospital, conscious state and triage.

Types of study to be included

No restriction

Condition or domain being studied

Conscious state, in the context of emergency calls for pre-hospital care

Participants/population

All patients presenting to emergency health services via an emergency telephone call

Intervention(s), exposure(s)

Altered conscious state, as determined by a call-taker

Comparator(s)/control

Fully conscious and alert patient, as determined by a call-taker

Context

Includes studies identifying conscious state recognition in any health condition or cause for the emergency call. Studies measuring accuracy of cardiac arrest recognition during an emergency call are excluded.

Main outcome(s) [1 change]

Accuracy of call-taker determination of patient conscious state when compared to actual initial findings at scene by first responders (by any appropriate measure).

Measures of effect

Not applicable.

Additional outcome(s) [1 change]

None.

Measures of effect

Not applicable.

Data extraction (selection and coding) [1 change]

Titles initially will be screened and then and abstracts will be reviewed, both by two reviewers to determine whether they meet inclusion criteria. Any disagreement will be resolved by discussion with a third reviewer.

Data to be extracted from included studies will include the study type, type of outcome measure, details of the qualifications of the assessors of conscious state both at telephone triage and on scene, and data sources for the studies; along with the data itself where available of numbers of true positives, true negatives, false positives and false negatives based on telephone triage and assessment at scene.

Risk of bias (quality) assessment [1 change]

Studies will be assessed using the QUADAS-2 tool. (https://www.bristol.ac.uk/population-health-sciences/projects/quadas/quadas-2/)

As per the QUADAS-2 tool, studies will be assessed for bias across the domains of:
- patient selection
- index test (i.e. calltaker determination)
- reference standard (i.e. on-scene assessment)
- flow and timing

Two researchers will review the studies based on this tool and any discrepancies will be resolved by discussion and if necessary referral to a third researcher.

Results of quality and bias assessment will not affect meta-analysis, but will be noted in the narrative synthesis.

Strategy for data synthesis [1 change]

Aggregate data extracted from the studies will be used to calculate and report measures of diagnostic accuracy (sensitivity, specificity, positive and negative predictive values) with 95% confidence intervals for the individual studies. Data from individual studies will be combined if studies are considered to be clinically comparable, and if heterogeneity (as determined by the I^2 statistic) is below 50%.

A narrative synthesis will also be performed.

Analysis of subgroups or subsets

If sufficient studies are found for specific medical conditions, data summaries will be sub-grouped by these condition types.

Contact details for further information

Jason Belcher
jason.belcher@postgrad.curtin.edu.au

Organisational affiliation of the review

Curtin University
https://healthsciences.curtin.edu.au/health-sciences-research/research-institutes-centres/precru/

Review team members and their organisational affiliations

Mr Jason Belcher. Curtin University
Dr Stephen Ball. Curtin University
Professor Judith Finn. Curtin University

Collaborators

Mr Austin Whiteside. St John Ambulance Western Australia

Type and method of review

Diagnostic, Systematic review

Anticipated or actual start date

01 April 2018

Anticipated completion date

30 June 2019

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None

Conflicts of interest

JB works as a paramedic with St John Ambulance Western Australia, and JF and SB have adjunct appointments with St John Ambulance Western Australia
Yes

Language

English

Country

Australia

Stage of review [2 changes]

Review Completed published

Details of final report/publication(s) or preprints if available [1 change]

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Consciousness; Emergency Medical Services; Humans; Telephone

Date of registration in PROSPERO

20 March 2019

Date of first submission

24 January 2019

Stage of review at time of this submission [2 changes]

Stage	Started	Completed
Preliminary searches	Yes	Yes
Piloting of the study selection process	Yes	Yes
Formal screening of search results against eligibility criteria	Yes	Yes
Data extraction	Yes	Yes
Risk of bias (quality) assessment	Yes	Yes
Data analysis	Yes	Yes

Revision note

Review now published. Status updated and publication details added.

The record owner confirms that the information they have supplied for this submission is accurate and complete and they understand that deliberate provision of inaccurate information or omission of data may be construed as scientific misconduct.

The record owner confirms that they will update the status of the review when it is completed and will add publication details in due course.

Versions

20 March 2019
11 November 2019
16 October 2020

Appendix 2: χ2 calculations for significance of difference between chief complaints (original analysis)

MPDS Chief Complaint	Total number of cases	Expected. true positives	Expected false positives	Observed. true positives.	Observed. false positives.	χ2 (PPV)	Expected false negatives	Expected. true negatives	Observed false negatives	Observed. true negatives	χ2 (NPV)
01 Abdo. pain/problems	5508	33.51	472.49	9	497	19.20	30.52	4971.48	6	4996	19.82
02 Allergies/Envenom.	1778	15.83	223.17	9	230	3.15	9.39	1529.61	8	1531	0.21
03 Animal bites/attacks	95	0.40	5.60	*	*	*	0.54	88.46	*	*	*
04 Assault/Sex. assault	2134	24.50	345.50	12	358	6.83	10.76	1753.24	11	1753	0.01
05 Back Pain	2483	7.42	104.58	0	112	7.94	14.46	2356.54	1	2370	12.61
06 Breathing problems	13,579	156.95	2213.05	188	2182	6.58	68.38	11,140.62	119	11,090	37.70
07 Burns/Explosion	250	0.20	2.80	*	*	*	1.51	245.49	*	*	*
08 CO/Inh/HAZ./CBRN	52	1.06	14.94	*	*	*	0.22	35.78	*	*	*
10 Chest Pain	16,162	67.28	948.72	25	991	28.46	92.40	15,053.60	25	15,121	49.47
11 Choking	107	0.66	9.34	*	*	*	0.59	96.41	*	*	*
13 Diabetic problems	1278	56.29	793.71	93	757	25.64	2.61	425.39	3	425	0.06
14 Drowning/Diving/SCUBA	31	0.99	14.01	*	*	*	0.10	15.90	*	*	*
15 Electroc./Lightning	31	0.13	1.87	*	*	*	0.18	28.82	*	*	*
16 Eye Problems	177	0.53	7.47	*	*	*	1.03	167.97	*	*	*
17 Falls	16,568	148.67	2096.33	96	2149	19.98	87.38	14,235.62	56	14,267	11.34
18 Headache	1606	18.34	258.66	4	273	12.01	8.11	1320.89	3	1326	3.24
19 Heart Probs/AICD.	3852	25.56	360.44	30	356	0.83	21.14	3444.86	12	3454	3.98
20 Heat/Cold exposure	57	1.59	22.41	*	*	*	0.20	32.80	*	*	*
21 Haemorrhage/Lacer.	5092	36.22	510.78	25	522	3.72	27.73	4517.27	28	4517	0.00
23 Overdose/Poisoning	3269	85.69	1208.31	122	1172	16.48	12.05	1962.95	45	1930	90.67
25 Psych./Suicide attempt	5597	65.83	928.17	45	949	7.06	28.08	4574.92	14	4589	7.10
26 Sick Person	14,309	150.26	2118.74	154	2115	0.10	73.45	11,966.55	159	11,881	100.25
27 Stab/Gunshot/Penet.	215	0.53	7.47	*	*	*	1.26	205.74	*	*	*
28 Stroke	3932	107.02	1508.98	159	1457	27.04	14.13	2301.87	27	2289	11.80
29 Traffic/Transport.	1493	4.57	64.43	4	65	0.08	8.69	1415.31	7	1417	0.33
30 Traumatic Injuries	3388	28.87	407.13	5	431	21.14	18.01	2933.99	8	2944	5.60
31 Unconscious/Fainting	6635	243.10	3427.90	294	3377	11.41	18.08	2945.92	14	2950	0.93
Total	109,678			1274	17,993	217.64			546	88,850	355.09

* χ2 values not calculated for rows with expected values <1

Appendix 3: χ2 calculations for significance of difference between chief complaints (alternative definition)

MPDS Chief Complaint	Total number of cases	Expected. true positives	Expected false positives	Observed. true positives.	Observed. false positives.	χ2 (PPV)	Expected false negatives	Expected. true negatives	Observed false negatives	Observed. true negatives	χ2 (NPV)
01 Abdo. pain/problems	5508	333.33	172.67	427	79	77.13	409.32	4592.68	183	4819	136.29
02 Allergies/Envenom.	1778	157.44	81.56	182	57	11.22	125.94	1413.06	48	1491	52.53
03 Animal bites/attacks	95	3.95	2.05	*	*	*	7.28	81.72	*	*	*
04 Assault/Sex. assault	2134	243.74	126.26	275	95	11.75	144.35	1619.65	150	1614	0.24
05 Back Pain	2483	73.78	38.22	85	27	5.00	194.02	2176.98	62	2309	97.84
06 Breathing problems	13,579	1561.27	808.73	1597	773	2.40	917.26	10,291.74	771	10,438	25.40
07 Burns/Explosion	250	1.98	1.02	*	*	*	20.21	226.79	*	*	*
08 CO/Inh/HAZ./CBRN	52	10.54	5.46	*	*	*	2.95	33.05	*	*	*
10 Chest Pain	16,162	669.30	346.70	860	156	159.22	1239.43	13,906.57	420	14726	590.04
11 Choking	107	6.59	3.41	*	*	*	7.94	89.06	*	*	*
13 Diabetic problems	1278	559.95	290.05	465	385	47.18	35.02	392.98	42	386	1.51
14 Drowning/Diving/SCUBA	31	9.88	5.12	*	*	*	1.31	14.69	*	*	*
15 Electroc./Lightning	31	1.32	0.68	*	*	*	2.37	26.63	*	*	*
16 Eye Problems	177	5.27	2.73	*	*	*	13.83	155.17	*	*	*
17 Falls	16,568	1478.92	766.08	1423	822	6.20	1172.08	13,150.92	1765	12,558	326.67
18 Headache	1606	182.48	94.52	220	57	22.61	108.75	1220.25	68	1261	16.63
19 Heart Probs/AICD.	3852	254.28	131.72	270	116	2.85	283.63	3182.37	149	3317	69.60
20 Heat/Cold exposure	57	15.81	8.19	*	*	*	2.70	30.30			
21 Haemorrhage/Lacer.	5092	360.34	186.66	390	157	7.15	371.93	4173.07	325	4220	6.45
23 Overdose/Poisoning	3269	852.44	441.56	653	641	136.74	161.62	1813.38	447	1528	548.83
25 Psych./Suicide attempt	5597	654.81	339.19	713	281	15.15	376.67	4226.33	491	4112	37.79
26 Sick Person	14,309	1494.73	774.27	1408	861	14.75	985.26	11,054.74	1689	10351	547.46
27 Stab/Gunshot/Penet.	215	5.27	2.73	*	*	*	16.94	190.06			
28 Stroke	3932	1064.56	551.44	943	673	40.68	189.52	2126.48	295	2021	63.93
29 Traffic/Transport.	1493	45.45	23.55	41	28	1.28	116.53	1307.47	71	1353	19.37
30 Traumatic Injuries	3388	287.22	148.78	323	113	13.06	241.57	2710.43	152	2800	36.17
31 Unconscious/Fainting	6635	2418.32	1252.68	2407	1264	0.16	242.55	2721.45	234	2730	0.33
Total	109,678			12,682	6585	574.53			7362	82,034	2577.10

* For comparison purposes, χ2 values not calculated for rows where it was not calculated in the primary analysis

Appendix 4: St John WA High Acuity Filter

(Note: referred to as Appendix 1 in the manuscript in Chapter 6)

Patients for whom any high acuity assessment or intervention item was present, were considered a high acuity patient.

Category	Description
Airway	At Risk/Unprotected
Airway	Complete Obstruction
Airway	Partial Obstruction
Airway	Soiled
Airway	Stridor
Bleeding	External considered > 500mls
Bleeding	Internal
Breathing	Accessory Muscle Use
Breathing	Audible Wheeze
Breathing	Laboured
Breathing	Nil
Breathing	Shallow
Breathing	Slow
Burns	Airway
Burns	Full Thickness
Capillary Refill	> 2 Seconds
Clinical Interventions	Mechanical CPR Device
Clinical Interventions	ST-Elevation Myocardial Infarction (STEMI)
Clinical Interventions	Stroke Centre Delivery
Collapse	Ambulance Officer Witnessed
Collapse	Bystander Witnessed
Electrocardiogram (ECG/EKG)	Asystole
Electrocardiogram (ECG/EKG)	Bradycardia
Electrocardiogram (ECG/EKG)	Pulseless Electrical Activity (PEA)
Electrocardiogram (ECG/EKG)	Supraventricular Tachycardia (SVT)
Electrocardiogram (ECG/EKG)	Ventricular Fibrillation (VF)
Electrocardiogram (ECG/EKG)	Ventricular Tachycardia (VT)
Glasgow Coma Scale (GCS) Total Score	Total <10
Glasgow Coma Scale (GCS) Motor response	1 None
Glasgow Coma Scale (GCS) Motor response	2 Extension to Pain
Glasgow Coma Scale (GCS) Motor response	3 Flexion to Pain
Glasgow Coma Scale (GCS) Verbal response	1 None
Glasgow Coma Scale (GCS) Verbal response	2 Incomprehensible
Head Gaze/Deviation	Present
Medications-Intervention	Adrenaline
Medications-Intervention	Amiodarone
Medications-Intervention	Atropine Sulphate
Medications-Intervention	Cefazolin
Medications-Intervention	Glucose 10%
Medications-Intervention	Heparin Sodium
Medications-Intervention	Ketamine
Medications-Intervention	Metaraminol Tartrate (Aramine)

Medications-Intervention	Morphine & Midazolam Infusion
Medications-Intervention	Naloxone
Medications-Intervention	Packed Red Blood Cells
Medications-Intervention	Rocuronium Bromide (Esmeron)
Medications-Intervention	Suxamethonium Chloride
Medications-Intervention	Tranexamic Acid (TXA)
Other finding	Amputation
Other finding	Partial Amputation
Post cardiac arrest	Return of Spontaneous Circulation (ROSC)
Post cardiac arrest	ROSC Temporary
Post defibrillation	No Rhythm Change
Post defibrillation	Rhythm Change
Pre-Ambulance Care	Automated External Defibrillator (AED) - Shock delivered
Pre-Ambulance Care	Cardio-pulmonary Resuscitation (CPR)
Pre-Ambulance Care	Ventilation Only
Problem Urgency	1 (Priority transport to ED)
Pulse	Nil
Pulse	Weak
Road Trauma	Ejected
Road Trauma	Rollover
Road Trauma	Trapped
Skills	Cardio-pulmonary Resuscitation (CPR)
Skills	Cricothyrotomy
Skills	Defibrillation
Skills	Endotracheal Tube
Skills	External Cardiac Pacing
Skills	Finger Thoracostomy
Skills	I-Gel Supraglottic Airway Device
Skills	Intraosseous Cannulation
Skills	Laryngeal Mask Airway
Skills	Magill Forceps
Skills	Needle Thoracentesis
Skills	Oropharyngeal Airway
Skills	Rapid Sequence Induction
Skills	Suction [of the airway]
Skills	Synchronised Cardioversion
Skills	Ventilator
Skin Colour	Cyanotic
Splint/Dressing	Combat Application Tourniquet (CAT)
Splint/Dressing	Traction Splint

Appendix 5: Case counts by MPDS protocol, conscious state, and High Acuity Filter

(Note: referred to as Appendix 2 in the manuscript in Chapter 6)

Conscious state	**Alert**		**Confused**		**Drowsy**		**Voice Response**		**Pain Response**		**Unresponsive**		**Total**
High Acuity	**Yes**	**No**	**Yes**	**No**	**Yes**	**No**	**Yes**	**No**	**Yes**	**No**	**Yes**	**No**	
01 Abdominal pain / problems	507	4808	36	126	34	62	5	3	4	1	3	0	**5589**
02 Allergies (reactions) / Envenomations (stings, bites)	282	1422	8	16	38	27	3	2	6	0	10	0	**1814**
03 Animal bites/attacks	4	98	0	0	1	0	0	0	0	0	0	0	**103**
04 Assault/Sexual assault	89	2068	17	124	26	110	12	6	13	3	10	0	**2478**
05 Back pain (non-traumatic / non-recent trauma)	161	2269	8	53	7	21	0	0	2	0	0	0	**2521**
06 Breathing problems	5441	6882	302	260	460	243	117	18	100	9	105	3	**13,940**
07 Burns (scalds) / Explosion (blast)	27	263	0	1	2	3	1	0	0	0	5	0	**302**
08 Carbon monoxide / inhalation / HAZMAT / CBRN	7	86	1	2	2	4	2	1	0	0	6	1	**112**
09 Cardiac or respiratory arrest/death	120	152	35	20	77	55	40	5	137	8	2208	33	**2890**
10 Chest pain (non-traumatic)	2505	13,228	70	229	90	146	15	7	12	5	16	0	**16,323**
11 Choking	97	254	5	6	8	10	4	0	9	1	17	1	**412**
12 Convulsions/Fitting	518	2048	241	500	292	493	122	42	237	27	214	1	**4735**
13 Diabetic problems	136	774	63	138	58	119	41	14	66	8	35	0	**1452**
14 Drowning (near) / Diving / SCUBA accident	5	34	0	1	1	0	1	0	1	0	12	0	**55**
15 Electrocution / Lightning	1	49	0	0	0	0	0	0	0	0	2	0	**52**
16 Eye problems / injuries	4	169	1	1	1	1	0	0	2	0	0	0	**179**
17 Falls	1720	12,746	367	1581	175	443	66	17	82	13	52	2	**17,264**
18 Headache	119	1383	8	36	20	57	3	1	2	0	1	0	**1630**
19 Heart problems / AICD	665	2974	45	89	38	55	18	2	15	4	5	0	**3910**
20 Heat/Cold exposure	7	40	1	3	1	6	0	0	0	1	0	1	**60**
21 Haemorrhage / Lacerations	552	4157	50	200	74	117	16	10	18	0	21	0	**5215**
22 Inaccessible incident / Other entrapments (non-vehicle)	3	28	0	0	0	1	0	1	0	0	1	0	**34**
23 Overdose/Poisoning (ingestion)	177	2225	48	151	240	676	47	26	185	24	142	1	**3942**
24 Pregnancy / Childbirth / Miscarriage	62	721	0	4	2	3	0	1	0	0	1	0	**794**
25 Psychiatric/Abnormal behaviour / Suicide attempt	198	4735	54	479	30	167	9	11	18	6	18	1	**5726**
26 Sick person (specific diagnosis)	1473	10,502	316	1036	308	628	88	48	123	24	45	1	**14,592**
27 Stab / Gunshot / Penetrating trauma	21	241	1	0	2	3	1	0	2	0	4	0	**275**
28 Stroke (cerebrovascular accident)	437	2570	150	393	101	144	67	18	70	7	27	0	**3984**
29 Traffic/Transportation incidents	398	3440	69	107	36	55	9	2	16	3	74	2	**4211**
30 Traumatic injuries (specific)	227	3003	47	119	25	85	7	2	2	3	2	0	**3522**
31 Unconscious/Fainting (near)	1465	4773	255	433	474	827	187	98	589	140	358	1	**9600**
32 Unknown problem	83	1018	21	84	34	102	10	22	23	19	59	1	**1476**
Total	**17,511**	**89,160**	**2219**	**6192**	**2657**	**4663**	**891**	**357**	**1734**	**306**	**3453**	**49**	**129192**

Appendix 6: Proportion of total cases at each level of consciousness, by MPDS code

(Note: referred to as Appendix 3 in the manuscript in Chapter 6)

Conscious state	Alert	Confused	Drowsy	Voice Response	Pain Response	Unresponsive
01 Abdominal pain / problems	95.10%	2.90%	1.72%	0.14%	0.09%	0.05%
02 Allergies (reactions) / Envenomations (stings, bites)	93.94%	1.32%	3.58%	0.28%	0.33%	0.55%
03 Animal bites/attacks	99.03%	0.00%	0.97%	0.00%	0.00%	0.00%
04 Assault/Sexual assault	87.05%	5.69%	5.49%	0.73%	0.65%	0.40%
05 Back pain (non-traumatic / non-recent trauma)	96.39%	2.42%	1.11%	0.00%	0.08%	0.00%
06 Breathing problems	88.40%	4.03%	5.04%	0.97%	0.78%	0.77%
07 Burns (scalds) / Explosion (blast)	96.03%	0.33%	1.66%	0.33%	0.00%	1.66%
08 Carbon monoxide / inhalation / HAZMAT / CBRN	83.04%	2.68%	5.36%	2.68%	0.00%	6.25%
09 Cardiac or respiratory arrest/death	9.41%	1.90%	4.57%	1.56%	5.02%	77.54%
10 Chest pain (non-traumatic)	96.39%	1.83%	1.45%	0.13%	0.10%	0.10%
11 Choking	85.19%	2.67%	4.37%	0.97%	2.43%	4.37%
12 Convulsions/Fitting	54.19%	15.65%	16.58%	3.46%	5.58%	4.54%
13 Diabetic problems	62.67%	13.84%	12.19%	3.79%	5.10%	2.41%
14 Drowning (near) / Diving / SCUBA accident	70.91%	1.82%	1.82%	1.82%	1.82%	21.82%
15 Electrocution / Lightning	96.15%	0.00%	0.00%	0.00%	0.00%	3.85%
16 Eye problems / injuries	96.65%	1.12%	1.12%	0.00%	1.12%	0.00%
17 Falls	83.79%	11.28%	3.58%	0.48%	0.55%	0.31%
18 Headache	92.15%	2.70%	4.72%	0.25%	0.12%	0.06%
19 Heart problems / AICD	93.07%	3.43%	2.38%	0.51%	0.49%	0.13%
20 Heat/Cold exposure	78.33%	6.67%	11.67%	0.00%	1.67%	1.67%
21 Haemorrhage / Lacerations	90.30%	4.79%	3.66%	0.50%	0.35%	0.40%
22 Inaccessible incident / Other entrapments (non-vehicle)	91.18%	0.00%	2.94%	2.94%	0.00%	2.94%
23 Overdose/Poisoning (ingestion)	60.93%	5.05%	23.24%	1.85%	5.30%	3.63%
24 Pregnancy / Childbirth / Miscarriage	98.61%	0.50%	0.63%	0.13%	0.00%	0.13%
25 Psychiatric/Abnormal behaviour / Suicide attempt	86.15%	9.31%	3.44%	0.35%	0.42%	0.33%
26 Sick person (specific diagnosis)	82.07%	9.27%	6.41%	0.93%	1.01%	0.32%
27 Stab / Gunshot / Penetrating trauma	95.27%	0.36%	1.82%	0.36%	0.73%	1.45%
28 Stroke (cerebrovascular accident)	75.48%	13.63%	6.15%	2.13%	1.93%	0.68%
29 Traffic/Transportation incidents	91.14%	4.18%	2.16%	0.26%	0.45%	1.80%
30 Traumatic injuries (specific)	91.71%	4.71%	3.12%	0.26%	0.14%	0.06%
31 Unconscious/Fainting (near)	64.98%	7.17%	13.55%	2.97%	7.59%	3.74%
32 Unknown problem	74.59%	7.11%	9.21%	2.17%	2.85%	4.07%
Total	**82.57%**	**6.51%**	**5.67%**	**0.97%**	**1.58%**	**2.71%**

Appendix 7: Proportion of high acuity cases at each individual level of consciousness, by MPDS code

(Note: referred to as Appendix 4 in the manuscript in Chapter 6)

	Alert	Confused	Drowsy	Voice Response	Pain Response	Unresponsive
01 Abdominal pain / problems	9.54%	22.22%	35.42%	62.50%	80.00%	100.00%
02 Allergies (reactions) / Envenomations (stings, bites)	16.55%	33.33%	58.46%	60.00%	100.00%	100.00%
03 Animal bites/attacks	3.92%	N/A	100.00%	N/A	N/A	N/A
04 Assault/Sexual assault	4.13%	12.06%	19.12%	66.67%	81.25%	100.00%
05 Back pain (non-traumatic / non-recent trauma)	6.63%	13.11%	25.00%	N/A	100.00%	N/A
06 Breathing problems	44.15%	53.74%	65.43%	86.67%	91.74%	97.22%
07 Burns (scalds) / Explosion (blast)	9.31%	0.00%	40.00%	100.00%	N/A	100.00%
08 Carbon monoxide / inhalation / HAZMAT / CBRN	7.53%	33.33%	33.33%	66.67%	N/A	85.71%
09 Cardiac or respiratory arrest/death	44.12%	63.64%	58.33%	88.89%	94.48%	98.53%
10 Chest pain (non-traumatic)	15.92%	23.41%	38.14%	68.18%	70.59%	100.00%
11 Choking	27.64%	45.45%	44.44%	100.00%	90.00%	94.44%
12 Convulsions/Fitting	20.19%	32.52%	37.20%	74.39%	89.77%	99.53%
13 Diabetic problems	14.95%	31.34%	32.77%	74.55%	89.19%	100.00%
14 Drowning (near) / Diving / SCUBA accident	12.82%	0.00%	100.00%	100.00%	100.00%	100.00%
15 Electrocution / Lightning	2.00%	N/A	N/A	N/A	N/A	100.00%
16 Eye problems / injuries	2.31%	50.00%	50.00%	N/A	100.00%	N/A
17 Falls	11.89%	18.84%	28.32%	79.52%	86.32%	96.30%
18 Headache	7.92%	18.18%	25.97%	75.00%	100.00%	100.00%
19 Heart problems / AICD	18.27%	33.58%	40.86%	90.00%	78.95%	100.00%
20 Heat/Cold exposure	14.89%	25.00%	14.29%	N/A	0.00%	0.00%
21 Haemorrhage / Lacerations	11.72%	20.00%	38.74%	61.54%	100.00%	100.00%
22 Inaccessible incident / Other entrapments (non-vehicle)	9.68%	N/A	0.00%	0.00%	N/A	100.00%
23 Overdose/Poisoning (ingestion)	7.37%	24.12%	26.20%	64.38%	88.52%	99.30%
24 Pregnancy / Childbirth / Miscarriage	7.92%	0.00%	40.00%	0.00%	N/A	100.00%
25 Psychiatric/Abnormal behaviour / Suicide attempt	4.01%	10.13%	15.23%	45.00%	75.00%	94.74%
26 Sick person (specific diagnosis)	12.30%	23.37%	32.91%	64.71%	83.67%	97.83%
27 Stab / Gunshot / Penetrating trauma	8.02%	100.00%	40.00%	100.00%	100.00%	100.00%
28 Stroke (cerebrovascular accident)	14.53%	27.62%	41.22%	78.82%	90.91%	100.00%
29 Traffic/Transportation incidents	10.37%	39.20%	39.56%	81.82%	84.21%	97.37%
30 Traumatic injuries (specific)	7.03%	28.31%	22.73%	77.78%	40.00%	100.00%
31 Unconscious/Fainting (near)	23.49%	37.06%	36.43%	65.61%	80.80%	99.72%
32 Unknown problem	7.54%	20.00%	25.00%	31.25%	54.76%	98.33%
Total	**16.42%**	**26.38%**	**36.30%**	**71.39%**	**85.00%**	**98.60%**

Appendix 8: Measures of diagnostic accuracy at each threshold level of consciousness, by MPDS code

(Note: referred to as Appendix 5 in the manuscript in Chapter 6)

01 Abdominal pain/problems

Threshold Level	Alert	Confused	Drowsy	Voice Response	Pain Response	Unresponsive
Sensitivity	1.0000	0.1392	0.0781	0.0204	0.0119	0.0051
Specificity	0.0000	0.9616	0.9868	0.9992	0.9998	1.0000
PPV	0.1054	0.2993	0.4107	0.7500	0.8750	1.0000
NPV	N/A	0.0954	0.0991	0.1035	0.1043	0.1049

02 Allergies (reactions)/Envenomations (stings, bites)

Threshold Level	Alert	Confused	Drowsy	Voice Response	Pain Response	Unresponsive
Sensitivity	1.0000	0.1873	0.1643	0.0548	0.0461	0.0288
Specificity	0.0000	0.9693	0.9802	0.9986	1.0000	1.0000
PPV	0.1913	0.5909	0.6628	0.9048	1.0000	1.0000
NPV	N/A	0.1655	0.1678	0.1829	0.1841	0.1868

04 Assault/Sexual assault

Threshold Level	Alert	Confused	Drowsy	Voice Response	Pain Response	Unresponsive
Sensitivity	1.0000	0.4671	0.3653	0.2096	0.1377	0.0599
Specificity	0.0000	0.8949	0.9485	0.9961	0.9987	1.0000
PPV	0.0674	0.2430	0.3389	0.7955	0.8846	1.0000
NPV	N/A	0.0413	0.0461	0.0542	0.0587	0.0636

05 Back pain (non-traumatic/non-recent trauma)

Threshold Level	Alert	Confused	Drowsy	Voice Response	Pain Response	Unresponsive
Sensitivity	1.0000	0.0955	0.0506	0.0112	0.0112	0.0000
Specificity	0.0000	0.9684	0.9910	1.0000	1.0000	1.0000
PPV	0.0706	0.1868	0.3000	1.0000	1.0000	N/A
NPV	N/A	0.0663	0.0678	0.0699	0.0699	0.0706

06 Breathing problems

Threshold Level	Alert	Confused	Drowsy	Voice Response	Pain Response	Unresponsive
Sensitivity	1.0000	0.1661	0.1198	0.0493	0.0314	0.0161
Specificity	0.0000	0.9281	0.9632	0.9960	0.9984	0.9996
PPV	0.4681	0.6704	0.7412	0.9148	0.9447	0.9722
NPV	N/A	0.4415	0.4457	0.4565	0.4605	0.4641

09 Cardiac or respiratory arrest/death

Threshold Level	Alert	Confused	Drowsy	Voice Response	Pain Response	Unresponsive
Sensitivity	1.0000	0.9541	0.9408	0.9113	0.8961	0.8437
Specificity	0.0000	0.5568	0.6300	0.8315	0.8498	0.8791
PPV	0.9055	0.9538	0.9606	0.9811	0.9828	0.9853
NPV	N/A	0.4412	0.4740	0.5054	0.5397	0.6302

10 Chest pain (non-traumatic)

Threshold Level	Alert	Confused	Drowsy	Voice Response	Pain Response	Unresponsive
Sensitivity	1.0000	0.0750	0.0491	0.0159	0.0103	0.0059
Specificity	0.0000	0.9716	0.9884	0.9991	0.9996	1.0000
PPV	0.1659	0.3441	0.4570	0.7818	0.8485	1.0000
NPV	N/A	0.1592	0.1606	0.1638	0.1645	0.1651

11 Choking

Threshold Level	Alert	Confused	Drowsy	Voice Response	Pain Response	Unresponsive
Sensitivity	1.0000	0.3071	0.2714	0.2143	0.1857	0.1214
Specificity	0.0000	0.9338	0.9559	0.9926	0.9926	0.9963
PPV	0.3398	0.7049	0.7600	0.9375	0.9286	0.9444
NPV	N/A	0.2764	0.2818	0.2895	0.2969	0.3122

12 Convulsions/Fitting

Threshold Level	Alert	Confused	Drowsy	Voice Response	Pain Response	Unresponsive
Sensitivity	1.0000	0.6810	0.5326	0.3528	0.2777	0.1318
Specificity	0.0000	0.6583	0.8190	0.9775	0.9910	0.9997
PPV	0.3430	0.5099	0.6057	0.8911	0.9415	0.9953
NPV	N/A	0.2019	0.2295	0.2568	0.2756	0.3119

13 Diabetic problems

Threshold Level	Alert	Confused	Drowsy	Voice Response	Pain Response	Unresponsive
Sensitivity	1.0000	0.6591	0.5013	0.3559	0.2531	0.0877
Specificity	0.0000	0.7350	0.8661	0.9791	0.9924	1.0000
PPV	0.2748	0.4852	0.5865	0.8659	0.9266	1.0000
NPV	N/A	0.1495	0.1791	0.1995	0.2219	0.2569

17 Falls

Threshold Level	Alert	Confused	Drowsy	Voice Response	Pain Response	Unresponsive
Sensitivity	1.0000	0.3014	0.1523	0.0812	0.0544	0.0211
Specificity	0.0000	0.8611	0.9679	0.9978	0.9990	0.9999
PPV	0.1426	0.2652	0.4412	0.8621	0.8993	0.9630
NPV	N/A	0.1189	0.1271	0.1328	0.1360	0.1400

18 Headache

Threshold Level	Alert	Confused	Drowsy	Voice Response	Pain Response	Unresponsive
Sensitivity	1.0000	0.2222	0.1699	0.0392	0.0196	0.0065
Specificity	0.0000	0.9364	0.9607	0.9993	1.0000	1.0000
PPV	0.0939	0.2656	0.3095	0.8571	1.0000	1.0000
NPV	N/A	0.0792	0.0821	0.0906	0.0922	0.0933

19 Heart problems/AICD

Threshold Level	Alert	Confused	Drowsy	Voice Response	Pain Response	Unresponsive
Sensitivity	1.0000	0.1539	0.0967	0.0483	0.0254	0.0064
Specificity	0.0000	0.9520	0.9805	0.9981	0.9987	1.0000
PPV	0.2010	0.4465	0.5547	0.8636	0.8333	1.0000
NPV	N/A	0.1827	0.1882	0.1935	0.1971	0.2000

21 Haemorrhage/Lacerations

Threshold Level	Alert	Confused	Drowsy	Voice Response	Pain Response	Unresponsive
Sensitivity	1.0000	0.2449	0.1765	0.0752	0.0534	0.0287
Specificity	0.0000	0.9271	0.9717	0.9978	1.0000	1.0000
PPV	0.1402	0.3538	0.5039	0.8462	1.0000	1.0000
NPV	N/A	0.1172	0.1214	0.1313	0.1337	0.1367

23 Overdose/Poisoning (ingestion)

Threshold Level	Alert	Confused	Drowsy	Voice Response	Pain Response	Unresponsive
Sensitivity	1.0000	0.7890	0.7318	0.4458	0.3897	0.1692
Specificity	0.0000	0.7170	0.7657	0.9836	0.9919	0.9997
PPV	0.2128	0.4299	0.4579	0.8800	0.9290	0.9930
NPV	N/A	0.0737	0.0865	0.1322	0.1426	0.1835

25 Psychiatric/Abnormal behaviour/Suicide attempt

Threshold Level	Alert	Confused	Drowsy	Voice Response	Pain Response	Unresponsive
Sensitivity	1.0000	0.3945	0.2294	0.1376	0.1101	0.0550
Specificity	0.0000	0.8770	0.9657	0.9967	0.9987	0.9998
PPV	0.0571	0.1627	0.2885	0.7143	0.8372	0.9474
NPV	N/A	0.0401	0.0461	0.0498	0.0512	0.0541

26 Sick person (specific diagnosis)

Threshold Level	Alert	Confused	Drowsy	Voice Response	Pain Response	Unresponsive
Sensitivity	1.0000	0.3740	0.2397	0.1088	0.0714	0.0191
Specificity	0.0000	0.8581	0.9427	0.9940	0.9980	0.9999
PPV	0.1613	0.3363	0.4458	0.7781	0.8705	0.9783
NPV	N/A	0.1230	0.1342	0.1470	0.1517	0.1587

28 Stroke (cerebrovascular accident)

Threshold Level	Alert	Confused	Drowsy	Voice Response	Pain Response	Unresponsive
Sensitivity	1.0000	0.4871	0.3110	0.1925	0.1138	0.0317
Specificity	0.0000	0.8206	0.9460	0.9920	0.9978	1.0000
PPV	0.2139	0.4248	0.6106	0.8677	0.9327	1.0000
NPV	N/A	0.1453	0.1654	0.1813	0.1946	0.2085

29 Traffic/Transportation incidents

Threshold Level	Alert	Confused	Drowsy	Voice Response	Pain Response	Unresponsive
Sensitivity	1.0000	0.3389	0.2243	0.1645	0.1495	0.1229
Specificity	0.0000	0.9532	0.9828	0.9981	0.9986	0.9994
PPV	0.1430	0.5469	0.6853	0.9340	0.9474	0.9737
NPV	N/A	0.1037	0.1163	0.1225	0.1244	0.1277

30 Traumatic injuries (specific)

Threshold Level	Alert	Confused	Drowsy	Voice Response	Pain Response	Unresponsive
Sensitivity	1.0000	0.2677	0.1161	0.0355	0.0129	0.0065
Specificity	0.0000	0.9349	0.9720	0.9984	0.9991	1.0000
PPV	0.0880	0.2842	0.2857	0.6875	0.5714	1.0000
NPV	N/A	0.0703	0.0807	0.0853	0.0871	0.0875

31 Unconscious/Fainting (near)

Threshold Level	Alert	Confused	Drowsy	Voice Response	Pain Response	Unresponsive
Sensitivity	1.0000	0.5598	0.4832	0.3407	0.2846	0.1076
Specificity	0.0000	0.7610	0.8300	0.9619	0.9775	0.9998
PPV	0.3467	0.5541	0.6013	0.8259	0.8704	0.9972
NPV	N/A	0.2349	0.2483	0.2667	0.2797	0.3214

32 Unknown problem

Threshold Level	Alert	Confused	Drowsy	Voice Response	Pain Response	Unresponsive
Sensitivity	1.0000	0.6391	0.5478	0.4000	0.3565	0.2565
Specificity	0.0000	0.8170	0.8844	0.9663	0.9839	0.9992
PPV	0.1558	0.3920	0.4667	0.6866	0.8039	0.9833
NPV	N/A	0.0754	0.0862	0.1028	0.1077	0.1208