

RESEARCH

# Pre-hospital early warning scores are associated with requirement for medical retrieval services

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## Abstract

**Objective:** Pre-hospital early warning scores (EWSs) can accurately identify patients at risk of clinical deterioration. We hypothesised that EWSs can identify patients during the pre-hospital phase who will subsequently require clinical escalation via medical retrieval.

**Methods:** A retrospective observational study of adult patients attended by Ambulance Victoria in rural regions in 2018 was conducted. We calculated EWSs using National Early Warning Score 2 (NEWS2) and Rapid Emergency Medicine Score (REMS) methods. Primary outcome was activation of Adult Retrieval Victoria (ARV) within 24 hours of ambulance attendance. We evaluated sensitivity and specificity for each score, and used multivariable logistic regression analysis to assess the independent association between EWSs and ARV activation.

**Results:** A total of 71,401 patients were included, of which 607 (0.9%) required ARV activation within 24 hours. Sensitivity and specificity of NEWS2 were 0.484 (95% CI 0.444–0.525) and 0.806 (95% CI 0.803–0.809) respectively, compared with 0.552 (95% CI 0.511–0.592) and 0.508 (95% CI 0.504–0.512) respectively for REMS. After adjustment for remoteness, distance to hospital, sex, age and hospital service level, a medium/high risk score according to the NEWS2 (OR 4.12; 95% CI 3.50–4.85,  $p < 0.001$ ) and REMS (OR 2.92, 95% CI 2.26–3.77) was associated with ARV activation. Odds of ARV activation increased with remoteness and decreasing service level of the receiving hospital.

**Conclusion:** Pre-hospital NEWS2 and REMS were associated with medical retrieval within 24 hours of ambulance attendance. EWSs may allow early identification of ambulance patients requiring medical retrieval, thus facilitating earlier activation and reduced time to definitive care.

## Keywords

early warning score; pre-hospital; retrieval medicine; ambulance; rural

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## INTRODUCTION

Patient early warning scores (EWSs) are used in hospital to aid early detection of patients at risk of clinical deterioration.<sup>(1,2)</sup> EWSs typically assign weighted values to routinely collected patient observations, allowing risk of deterioration to be quantified on a numerical scale.<sup>(3)</sup> The results are used to guide clinical response, escalation of care and resource allocation decisions.<sup>(3)</sup> EWSs are not commonly employed in the pre-hospital setting; however recent studies have validated their use in this environment.<sup>(3–8)</sup>

Various pre-hospital EWSs have been evaluated, including the National Early Warning Score 2 (NEWS2) developed by the Royal College of Physicians, United

Kingdom, and the Rapid Emergency Medicine Score (REMS), a version of Rapid Acute Physiology Score modified by Olsson et al.<sup>(9)</sup> Studies have demonstrated their ability to predict patient outcomes such as critical care escalation and short-term mortality.<sup>(5,6,9,10)</sup> The NEWS2 is widely used in the United Kingdom and internationally, and is recommended for use in the pre-hospital setting.<sup>(11)</sup> REMS was originally developed for in-hospital use; however studies have shown its ability to measure severity of illness in the pre-hospital environment.<sup>(12)</sup>

Despite the potential utility of pre-hospital EWSs, there is no clear evidence in support of specific applications.<sup>(6,13)</sup> They have been proposed as a guidance tool for triggering a pre-alert notification to the

receiving emergency department (ED) (14,15) as this can reduce the time to initiate an appropriate clinical response upon arrival at hospital.(5,13) Identifying patients in the pre-hospital phase who require urgent clinical review or escalation may also improve outcomes, particularly for those with a time-critical illness.(4)

In Australia, where populations are concentrated in major cities, there is a disproportionate distribution of medical services between rural and urban areas.(16) This clinical services provision gap contributes to delays for accessing specialist and tertiary services.(17) Retrieval medicine – the transfer of patients by specialised clinical staff utilising road-based and aeromedical platforms – provides a vital link to critical medical services, particularly for those in rural and remote locations.(18,19) The decision-making process to activate retrieval services is complex, with consideration given to presenting pathology, physiological instability, comorbidities, local availability of medical services, geography, weather and availability of retrieval resources.(17,19) Several hours can elapse from patient presentation to decision to transfer to another facility. These delays can have a deleterious effect on patient outcomes, as well as complicating tasking decisions due to the limited availability of retrieval resources.(20) Early identification of patients needing medical retrieval may expedite activation of the service, thereby reducing delays in accessing definitive care.

We hypothesise that EWSs can identify patients during the pre-hospital phase who will subsequently require clinical escalation via medical retrieval. The primary aim of this study was to investigate and compare the ability of pre-hospital NEWS2 or REMS to predict the need for clinical escalation via medical retrieval. This would present an opportunity to identify these patients at the earliest point of medical care. The secondary aim was to determine other factors that influence the requirement for medical retrieval in the study population.

## METHODS

This retrospective observational cohort study examined associations between pre-hospital EWSs and activation of a state-wide medical retrieval service, Adult Retrieval Victoria (ARV). The primary outcome measure was activation of ARV within 24 hours of the patient being transported to hospital by ambulance. NEWS2 was selected as it is the most widely used EWS internationally and is recommended for pre-hospital use.(11) REMS was included for comparison as it forms part of the ARV triage guidelines for retrieval activation.(19) Both are easily calculated using routinely collected pre-hospital patient observations.

### Setting

The study was located in the State of Victoria, Australia – an area of 240,000 km<sup>2</sup> with a population of 6.5 million. The study involved patients attended by the state-wide emergency medical service, Ambulance Victoria (AV), in rural Victoria between 1 January 2018

and 31 December 2018. The five rural districts of AV service a population of approximately 1.3 million, with ambulance crews attending about 500 cases per day.(21)

### Inclusion criteria

Patients aged > 17 years were recruited if they were attended and transported by ambulance during the study period. Patients recorded as suffering from major trauma, obstetric problems or cardiac arrest were excluded as these patients are typically managed according to specific guidelines. Further exclusions were applied for ARV activations > 24 hours from initial ambulance attendance, unrealistic values for age or where there were insufficient data to calculate patient EWSs. A cut-off for ARV activation > 24 hours was chosen as medical retrievals after this period likely did not relate to the initial ambulance presentation.

### Datasets

AV ambulance crews complete an electronic care record for each patient on a portable computer, with data from these records uploaded to a clinical data warehouse. Data were extracted from the data warehouse and ambulance responses matched with ARV activations using probabilistic linkage.

Variables extracted from the database included age, sex, date, time of ambulance attendance, location, destination hospital, distance to hospital, final paramedic diagnosis, comorbidities, use of oxygen during treatment and vital signs. Vital signs included were heart rate, respiratory rate, peripheral oxygen saturation, Glasgow Coma Scale (GCS), systolic blood pressure (SBP), diastolic blood pressure (DBP) and temperature. Patient observations are manually entered by the ambulance personnel into the portable computer. Patient observations for heart rate, blood pressure (BP) and oxygen saturations are routinely obtained using a Zoll X series monitor/defibrillator, although BP may be measured manually. Patient temperature is recorded using a handheld tympanic thermometer. GCS was converted to an AVPU (alert, responds to voice, responds to pain, unresponsive) scale based on a protocol previously described by Smith et al.(22) Mean arterial pressure was calculated from SBP and DBP values.

EWSs were calculated retrospectively for each patient using both the NEWS2 (Table S1) and REMS (Table S2) scoring systems. Scores were calculated from first and final recorded clinical observations to allow comparison. First clinical observations were performed during initial contact with the patient, typically within a few minutes of patient arrival. Final observations were performed on arrival at hospital, or when the patient is handed over to another clinician. Where a final dataset was incomplete, the missing value(s) was/were considered equivalent to the first recording. This was appropriate, as most ambulance cases are of relatively short duration. NEWS2 and REMS scores were then stratified into low,

medium and high-risk groups using previously described criteria.(8,23)

Remoteness category for each case was determined from the event postcode using the Australian Institute of Health and Welfare remoteness criteria.(24) Destination hospital was stratified by care service level based on state government classifications for rural trauma services. This was considered an appropriate analogue of medical and critical care services available at a particular facility

### Data analysis

Data were analysed using SPSS Statistics v.26 (IBM, Armonk, NY, USA). We used descriptive statistics to describe the characteristics of the cohort overall and separately according to ARV activation. Categorical data were compared using the  $\chi^2$  test, and continuous data were compared using the Mann-Whitney U test for independent samples.

Results based on NEWS2 and REMS were explored independently and then compared. The performance of the two systems was explored using sensitivity and specificity analysis, with the overall performance of NEWS2 and REMS evaluated using area under the receiver operator characteristic (AUROC).

Median and interquartile range (IQR) were calculated for initial and final EWSs for both NEWS2 and REMS. The difference between first and final scores was examined using Wilcoxon Signed Ranks test for paired samples.

Proportions of ARV activations for each EWS risk group were compared using the  $\chi^2$  test. Unadjusted odds ratios (ORs) for each risk group were analysed using binary logistic regression. Multivariable logistic regression was used to evaluate the independent association between EWS risk groups and ARV activation, adjusting for age, sex, distance to hospital, remoteness and hospital service level.

### Ethics approval

The research protocol was approved by the Research Governance Committee of Ambulance Victoria. Ethical approval for the study was granted by the Monash University Human Research Ethics Committee. Patient anonymity was preserved with a de-identified dataset being provided to investigators

## RESULTS

During the study period there were 110,643 primary ambulance responses for patients aged > 17 years. After excluding trauma and obstetric cases, cardiac arrests, unrealistic ages and incomplete records, 71,401 patients were included in analyses (Figure S1).

Descriptive statistics of the cohort overall as well as by outcome group are presented in Table 1.

The median age for the overall cohort was 67 (IQR 49–80) years, and 47.7% were male. The proportion of males was higher in the ARV activation outcome group (57.3% vs. 47.6%,  $p < 0.001$ ), and the median age was lower (63 vs. 67 years,  $p < 0.001$ ). The primary outcome

**Table 1.** Patient characteristics according to ARV activation (n=71,401)

	Total	ARV activated	ARV not-activated	p-value
<b>Cases, n (%)</b>	71,401 (100)	607 (0.9)	70,794 (99.1)	
<b>Age (years), median (IQR)</b>	67 (49–80)	63 (50–74)	67 (49–80)	0.001*
<b>Sex</b>				
Male, n (%)	34,055 (47.7)	348 (57.3)	33,707 (47.6)	< 0.001*
Female, n (%)	37,312 (52.3)	259 (42.7)	37,053 (52.4)	
Not-specified n(%)	34 (< 0.1)	0 (0.0)	34 (< 0.1)	
Mean time to ARV activation, hours (SD)		5.87 (5.29)		
<b>Remoteness, n (%)</b>				
Major cities	8695 (12.2)	12 (2.0)	8683 (12.3)	< 0.001**
Inner regional	49,139 (68.8)	349 (57.5)	48,790 (68.9)	
Outer regional	13,445 (18.8)	245 (40.4)	13,200 (18.6)	
Remote	114 (0.2)	1 (0.2)	113 (0.2)	
<b>Final diagnosis category, n (%)</b>				
Alcohol/drugs	2663 (3.7)	53 (8.7)	2610 (3.7)	< 0.001**
Cardiovascular	8798 (12.3)	87 (14.3)	8711 (12.3)	
Gastrointestinal	3809 (5.3)	34 (5.6)	3775 (5.3)	
Medical	17,565 (24.6)	82 (13.5)	17,483 (24.7)	
Neurological	11,507 (16.1)	150 (24.7)	11,357 (16.0)	
Respiratory	8962 (12.6)	59 (9.7)	8903 (12.6)	
Sepsis/infection	3394 (4.8)	50 (8.2)	3344 (4.7)	
Other†	14,703 (20.6)	92 (15.2)	14,611 (20.5)	

\*Mann-Whitney U test for independent samples; \*\* $\chi^2$  test. †Final diagnosis, 'other', includes diagnostic categories allergic reaction, dermatological, endocrine, environmental, mental health, minor trauma, urological and other medical or unspecified. ARV: Adult Retrieval Victoria; IQR: interquartile range; SD: standard deviation

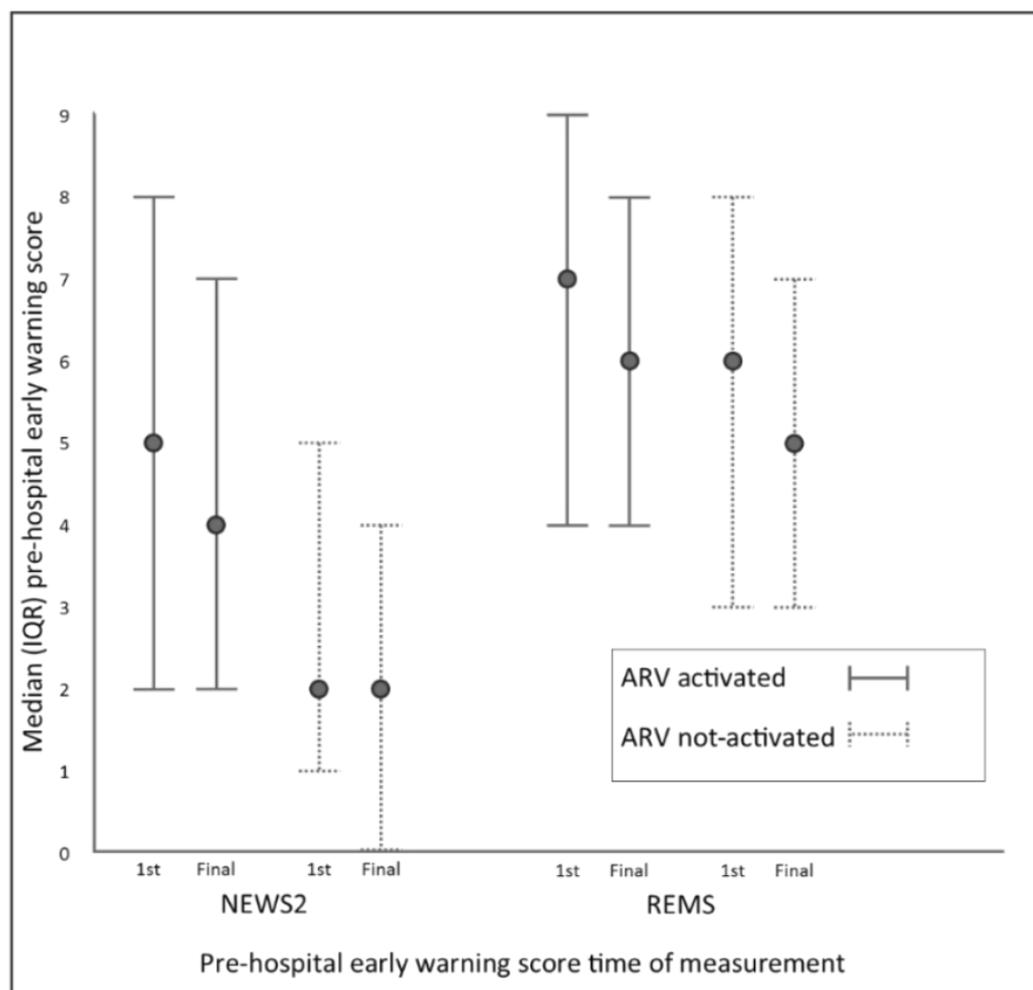
of ARV activation within 24 hours of primary ambulance response occurred in 607 (0.9%) patients, with a mean time from initial ambulance call to medical retrieval activation of 5.87 hours (SD 5.29).

The overall range for NEWS2 was 0–20. The median for first and final NEWS2 (Figure 1) was 2 (IQR 1–5 and 0–4 respectively). A mean difference of -0.69 (95% CI -0.68 to -0.71,  $p < 0.001$ ) between the scores was observed. The median final NEWS2 was higher in the ARV-activated than for the not-activated group (4, IQR: 2–7 vs. 2, IQR: 0–4;  $p < 0.001$ ).

For REMS, the range was 0–23, with median scores for first and final REMS being 6 (IQR 3–8) and 5 (IQR 3–7) respectively. The mean difference between the scores was -0.59 (CI 95% -0.58 to -0.60,  $p < 0.001$ ). Similar to NEWS2, the final REMS in the ARV-activation outcome group was higher than in the non-activated group (6, IQR: 4–8 vs. 5, IQR: 3–7;  $p < 0.001$ ). As final NEWS2 and REMS were lower than initial scores, the rest of the paper will focus on the final values as these allow for the effects of pre-hospital treatment.

When considering clinical risk categories (Table 2), both NEWS2 and REMS were associated with ARV activation. For final NEWS2, the unadjusted ORs for medical retrieval for medium and high-risk categories compared to low risk were 2.73 (95% CI 2.19–3.40,  $p < 0.001$ ) and 5.21 (95% CI 4.33–6.26,  $p < 0.001$ ), respectively. Similarly, the medium and high-risk REMS ORs were 1.25 (95% CI 1.06–1.47;  $p = 0.007$ ) and 6.11 (95% CI 2.98–12.54,  $p < 0.001$ ), respectively.

Sensitivity, specificity and AUROC are reported in Table 3 for both scoring systems. NEWS2 had an AUROC of 0.688 (0.665–0.711), whereas for REMS it was 0.576 (0.544–0.599). When a cut-off for medium risk NEWS2 ( $\geq 5$ ) was applied, a sensitivity of 0.484 (95% CI 0.444–0.525) and specificity of 0.806 (95% CI 0.803–0.809) was observed. For REMS, a medium-risk cut-off ( $\geq 6$ ) was similarly applied with sensitivity and specificity observed as 0.552 (95% CI 0.511–0.592) and 0.508 (95% CI 0.504–0.512), respectively.



ARV: Adult Retrieval Victoria; IQR: interquartile range; NEWS2: National Early Warning Score 2; REMS: Rapid Emergency Medicine Score.

**Figure 1.** Median (IQR) first and final pre-hospital NEWS2 and REMS scores, according to ARV activation

**Table 2.** ARV activations according to NEWS2 and REMS risk category

	ARV activation status					
	Overall n (%)	Activated n (%)	Not activated n (%)	p-value*	Unadjusted ORs** (CI: 95%)	p-value**
<b>NEWS2</b>						
Low (0–4)	57,356 (80.3)	313 (51.6)	57,043 (80.6)	< 0.001	Reference	
Medium (5–6)	7384 (10.3)	109 (18.0)	7275 (10.3)		2.73 (2.19–3.40)	< 0.001
High (≥ 7)	6661 (9.3)	185 (30.5)	6476 (9.1)		5.21 (4.33–6.26)	< 0.001
<b>REMS</b>						
Low (0–5)	36,231 (50.7)	272 (44.8)	35,959 (50.8)	< 0.001	Reference	
Medium (6–13)	34,989 (49.0)	327 (53.9)	34,662 (49.0)		1.25 (1.06–1.47)	0.007
High (≥ 14)	181 (0.3)	8 (1.3)	173 (0.2)		6.11 (2.98–12.54)	< 0.001

ARV: Adult Retrieval Victoria; NEWS2: National Early Warning Score 2; CI: confidence interval; OR: odds ratio; REMS: Rapid Emergency Medicine Score (values obtained from final observations)

\* $\chi^2$  test; \*\*ORs and p-values obtained from binary logistic regression.

Multivariable logistic regression analysis (Table 4) was used to evaluate the effect of potential confounders. Level of remoteness was associated with an increased risk of ARV activation for both NEWS2 and REMS, with patients in inner- and outer-regional areas having a significantly increased risk of requiring medical retrieval when compared to those in major cities. Hospital service level was inversely associated, with patients more likely to require ARV activation if taken to a lower level facility such as an urgent care service.

## DISCUSSION

Our study demonstrated an association between increased pre-hospital EWS and subsequent need for medical retrieval of non-trauma patients in rural areas. Previous studies have evaluated pre-hospital EWSs using outcomes such as early mortality and clinical escalation to intensive care unit (5–8,25,26) and the results from our study are comparable with those findings. It is acknowledged, however, that ARV activation is influenced by several outside factors and not solely based on clinical instability measured at a point in time.

**Table 3.** Sensitivity and specificity of medium/high risk NEWS2 and REMS for predicting ARV activation

	NEWS2 (≥ 5) (95% CI)	REMS (≥ 6) (95% CI)
<b>Sensitivity</b>	0.484 (0.444–0.525)	0.552 (0.511–0.592)
<b>Specificity</b>	0.806 (0.803–0.809)	0.508 (0.504–0.512)
<b>PPV</b>	0.021 (0.019–0.023)	0.010 (0.009–0.010)
<b>NPV</b>	0.995 (0.994–0.995)	0.993 (0.992–0.993)
<b>PLR</b>	2.49 (2.29–2.71)	1.12 (1.04–1.21)
<b>NLR</b>	0.64 (0.59–0.69)	0.88 (0.81–0.96)
<b>AUROC</b>	0.688 (0.665–0.711)	0.576 (0.554–0.599)

ARV: Adult Retrieval Victoria; AUROC: area under the receiver operator characteristic; NEWS2: National Early Warning Score 2; NLR: Negative Likelihood Ratio; NPV: Negative Predictive Value; PLR: Positive Likelihood Ratio; PPV: Positive Predictive Value; REMS: Rapid Emergency Medicine Score. NEWS2 and REMS calculated from final patient observations.

In our study, the risk of ARV activation was increased for people in more remote areas, and for patients taken to lower service level hospitals. This finding reinforces the concept of a clinical service provision gap experienced by patients in rural and remote areas. However, even when these factors were controlled for, the odds of requiring medical retrieval were significantly higher for patients with medium and high-risk EWSs. This finding suggests that a substantial proportion of patients who require medical retrieval may be identified during the pre-hospital phase.

The mean time to ARV activation of 5.87 hours represents a considerable delay from initial patient presentation to decision to transfer to definitive care. For certain pathologies, late notification of a patient requiring urgent transfer may impact patient mortality and morbidity; however the effect of delayed medical retrieval on overall patient outcome was beyond the scope of this study. Earlier identification of patients likely to require medical retrieval may be of benefit to those making decisions for the triage and tasking of aeromedical and road-based retrieval platforms.(20) For example, knowing that a patient in a remote location will likely require urgent aeromedical retrieval in the near future could influence the decision to deploy those resources for a less critical patient.

A review published in 2019 identified the possibility of integrating pre-hospital REMS into a system for prompting aeromedical retrieval.(12) The findings of our study suggest NEWS2 might be a more reliable tool than REMS. The poorer performance of REMS in comparison to NEWS2 may be explained by the addition of an age-based weighting for REMS calculations, as the cohort age was positively skewed. If a pre-hospital EWS was to be used to pre-alert medical retrieval services, further evaluation of the best scale and appropriate cut-off value is required.

The time at which EWSs were measured was significant in this study, with scores for NEWS2 and REMS being

**Table 4.** Multivariable logistic regression assessing factors independently associated with ARV activation

	NEWS2		REMS	
	OR (95% CI)	p-value	OR (95% CI)	p-value
<b>Sex (male)</b>	1.44 (1.22–1.70)	< 0.001	1.49 (1.27–1.76)	< 0.001
<b>Age (years)</b>	0.99 (0.98–0.99)	< 0.001	0.97 (0.97–0.98)	< 0.001
<b>Distance to hospital (km)</b>	1.00 (1.00–1.01)	0.157	1.00 (1.00–1.01)	0.159
<b>Remoteness</b>				
Major city	Reference		Reference	
Inner regional	4.67 (2.62–8.34)	< 0.001	4.74 (2.66–8.45)	< 0.001
Outer regional	10.71 (5.94–19.33)	< 0.001	11.14 (6.18–20.09)	< 0.001
Remote	7.29 (0.89–59.62)	0.064	8.18 (1.01–66.01)	0.049
<b>Hospital level</b>				
Metropolitan	Reference		Reference	
Regional trauma service	1.93 (1.10–3.39)	0.022	1.99 (1.13–3.48)	0.017
Urgent care service	3.03 (1.70–5.38)	< 0.001	2.87 (1.62–5.10)	< 0.001
Primary care service/seasonal	1.19 (0.26–5.35)	0.824	1.05 (0.23–4.74)	0.946
<b>Risk category</b>				
Low	Reference		Reference	
Medium/high	4.12 (3.50–4.85)	< 0.001	2.92 (2.26–3.77)	< 0.001

ARV: Adult Retrieval Victoria; CI: confidence interval; NEWS2: National Early Warning Score 2; OR: odds ratio; REMS: Rapid Emergency Medicine Score.

lower for the final set of observations. This indicated an overall, albeit small, improvement in patient condition during paramedic care. Previous studies have had contrasting results with respect to this issue.(6,8) In their study, Shaw et al. (8) found there was no difference, whereas Abbott et al. (6) report an improvement between the pre-hospital score and that obtained on admission to ED. Early calculation allows more time for early clinical decision making, whereas later calculation considers the effect of any pre-hospital interventions initiated by the ambulance crew. For example, a patient presenting with a hypoglycaemic episode, seizure, or a narcotic overdose will initially have extreme derangements of their physiological parameters; however, these patients can, in many cases, be definitively treated or undergo significant improvements in the pre-hospital environment. In the context of medical retrieval, with limited retrieval resources available, it may be appropriate to consider the final score to allow for initial pre-hospital treatment and potential stabilisation of the patient.

A pre-hospital EWS cannot replace clinical judgement as there are many factors which influence the activation of medical retrieval. The low sensitivity and specificity scores indicate that a pre-hospital EWS would be a poor proxy for more detailed evaluation. The high proportion of patients in this study with low-risk EWS who required ARV activation reinforces that physiological instability is not the only determining factor. For example, the requirement for certain medical services based on pathology specific findings, such as ST-segment elevation in acute myocardial infarction, will dictate the necessity for medical transfer regardless of physiological status. For other non-specific pathologies or presentations, the detection of an abnormal medium or high-risk score in a patient during the pre-hospital phase

should prompt early follow-up with the receiving hospital for potential medical retrieval.

### Limitations

This study relied on data collected by paramedics in the field. Sub-optimal recording of pre-hospital observations has been identified in other studies.(4) A substantial number of cases were eliminated from analysis due to missing values, with DBP and temperature the most common missing values. Patients were eliminated where it was not possible to calculate a single NEWS2 and REMS; however, where only final values were missing, they were assumed to be equivalent to the first. The purpose of this was to maintain a large sample size; however it also assumes that the patient condition did not change. This may have affected the difference measured between the first and final EWS measurements.

A patient's past medical history would be considered in the process for planning medical retrieval. Evaluation of the influence of comorbidities was planned; however this was not possible in the study due to unreliable recording of past medical history data by paramedics.

The influence of local health services and geographical factors in the decision process to activate a medical retrieval service will be different for each jurisdiction. Each state of Australia has unique challenges for provision of pre-hospital and critical care services. The findings of this study, therefore, may not be generalisable to other jurisdictions.

### CONCLUSION

Triage and tasking of medical retrieval services is complex. Pre-hospital NEWS2 and REMS are

associated with the need for subsequent medical retrieval, with NEWS2 having an overall better performance. This information may be useful for development of medical retrieval guidelines. Further studies are required to evaluate what impact earlier identification may have on patient outcome and how to improve the performance of NEWS2 as a pre-alerting tool.

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## Author contributions

JS was responsible for research protocol construction, data analysis and manuscript preparation. EA and KS contributed to the design of the study, the analysis and interpretation of the data. EA extracted the data. KS provided project supervision and revision of the final draft.

## COMPETING INTERESTS

The authors declare no competing interests. Each author of this paper has completed the ICMJE conflict of interest statement.

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## SUPPLEMENTARY MATERIALS

**Table S1.** Early warning scores calculated retrospectively for each patient using NEWS2

Physiological parameter	Score						
	3	2	1	0	1	2	3
Respirations min <sup>-1</sup>	≤ 8		9–11	12–20		21–24	≥ 25
Oxygen saturation (%)	≤ 91	92–93	94–95	≥ 96			
Air or oxygen?		Oxygen		Air			
SBP (mmHg)	≤ 90	91–100	101–110	111–219			≥ 220
Pulse min <sup>-1</sup>	≤ 40		41–50	51–90	91–110	111–130	≥ 131
Level of consciousness				Alert			VPU†
Temperature (°C)	≤ 35.0		35.1–36.0	36.1–38	38.1–39.0	≥ 39.1	

†V = responsive to voice, P = responsive to pain, U = unresponsive.

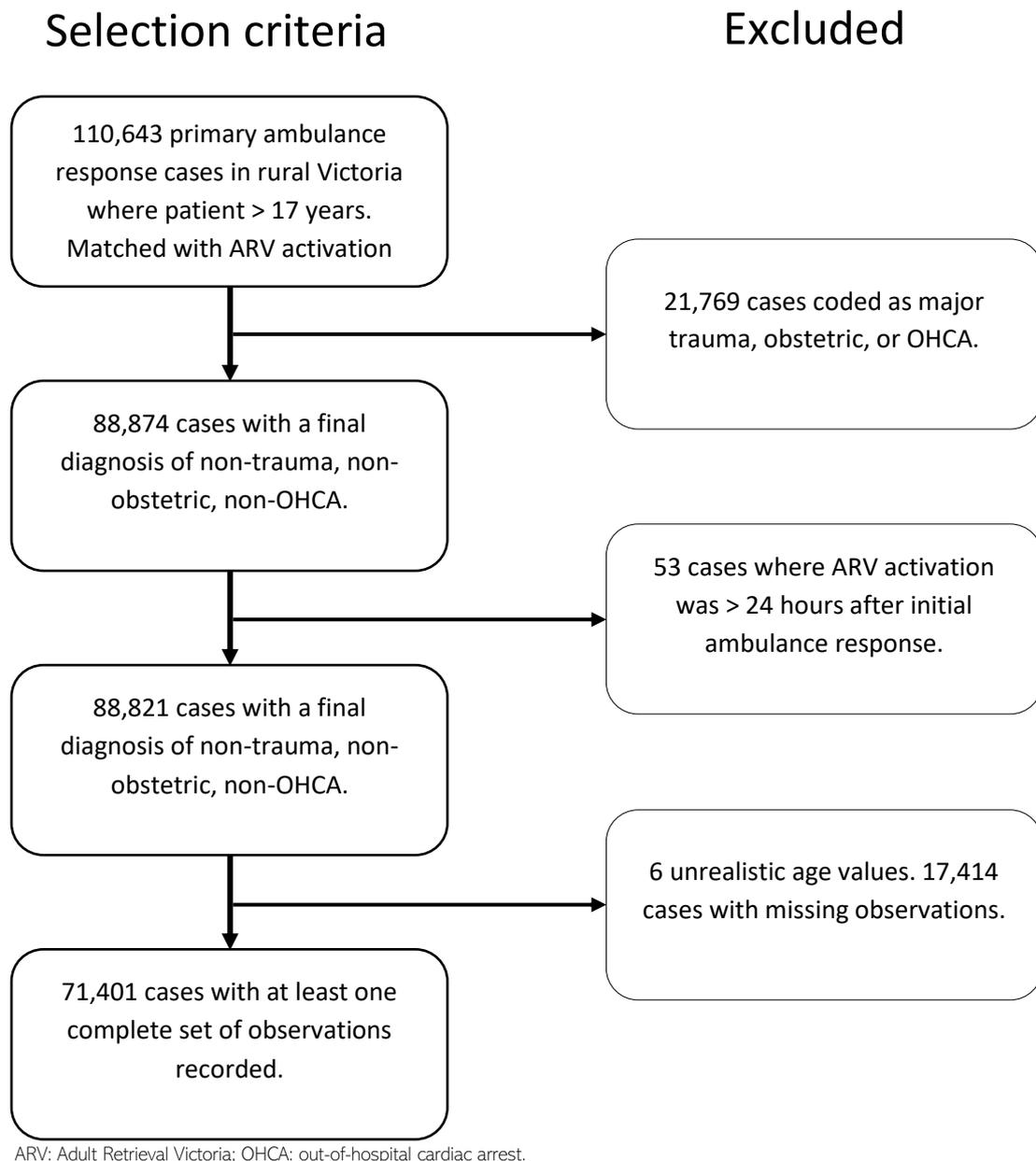
NEWS2 = National Early Warning Score 2; SBP = systolic blood pressure.

**Table S2.** Early warning scores calculated retrospectively for each patient using REMS

Variable	Score						
	0	+1	+2	+3	+4	+5	+6
Age (years)	< 45		45–54	55–64		65–74	> 74
MAP (mmHg)†	70–109		110–129	130–159	> 159		
Heart rate min <sup>-1</sup>	70–109		50–69	140–179	≤ 49		
Respirations min <sup>-1</sup>	12–24	25–34	110–139	140–179	> 179		
O <sub>2</sub> saturation (%)	> 89	10–11	55–69	40–54	≤ 39		
GCS	14 or 15	86–89	6–9	35–49	> 49		
		11–13	8–10	5–7	≤ 5		
					< 75		
					3 or 4		

†MAP calculated retrospectively from values for SBP and DBP using formula  $MAP = DBP + ((SBP - DBP) / 3)$ .

DBP = diastolic blood pressure; GCS = Glasgow Coma Scale; MAP = mean arterial pressure; REMS = Rapid Emergency Medicine Score; SBP = systolic blood pressure.



**Figure S1.** Application of exclusion criteria for study cohort, 1 January 2018 to 31 December 2018