Healthcare cost burden of acute chest pain presentations

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ABSTRACT

Background This study aimed to estimate the direct healthcare cost burden of acute chest pain attendances presenting to ambulance in Victoria, Australia, and to identify key cost drivers especially among low-risk patients.

Methods State-wide population-based cohort study of consecutive adult patients attended by ambulance for acute chest pain with individual linkage to emergency and hospital admission data in Victoria, Australia (1 January 2015–30 June 2019). Direct healthcare costs, adjusted for inflation to 2020–2021 ($A), were estimated for each component of care using a casemix funding method.

Results From 241 627 ambulance attendances for chest pain during the study period, mean chest pain episode cost was $6284, and total annual costs were estimated at $337.4 million ($68 per capita per annum). Total annual costs increased across the period ($310.5 million in 2015 vs $384.5 million in 2019), while mean episode costs remained stable. Cardiovascular conditions (25% of presentations) were the most expensive (mean $11 523, total annual $148.7 million), while a non-specific pain diagnosis (49% of presentations) was the least expensive (mean $3836, total annual $93.4 million). Patients classified as being at low risk of myocardial infarction, mortality or hospital admission (Early Chest pain Admission, Myocardial infarction, and Mortality (ECAMM) score) represented 31%–57% of the cohort, with total annual costs estimated at $60.6 million–$135.4 million, depending on the score cut-off used.

Conclusions Total annual costs for acute chest pain presentations are increasing, and a significant proportion of the cost burden relates to low-risk patients and non-specific pain. These data highlight the need to improve the cost-efficiency of chest pain care pathways.

WHAT IS ALREADY KNOWN ON THIS TOPIC

⇒ Acute chest pain is one of the most common reasons for medical contact, and assessment processes can be lengthy and resource-intensive.

WHAT THIS STUDY ADDS

⇒ In this population-based study, total annual costs for acute chest pain presentations were increasing, and a significant proportion of the cost burden related to low-risk patients and non-specific pain.

HOW THIS STUDY MIGHT AFFECT RESEARCH, PRACTICE OR POLICY

⇒ These data highlight an urgent need to improve the cost-efficiency of chest pain care pathways especially for low-risk patients.

INTRODUCTION

Acute chest pain is one of the most common reasons for medical contact and is associated with significant health expenditure.[1–4] Rapid diagnosis and management are prioritised in order to exclude serious pathologies such as myocardial infarction, but approximately 50% of patients presenting with chest pain can be safely discharged following assessment without a specific diagnosis.[4] Previous studies have demonstrated that there are significant costs in assessing low-risk patients with chest pain that do not have a serious underlying pathology.[1] However, over the last decade, there have been improvements in the efficiency of clinical decision pathways for chest pain and the availability of high-sensitivity troponin assays,[4–7] which may have led to reductions in costs among some groups. Given the frequency of chest pain presentations and the often expensive workup processes, it is important to understand which factors drive the financial burden. This information, in turn, could be used to determine which aspects of care might be modified to improve cost-efficiency without compromising patient clinical outcomes.

In this study, we aimed to estimate the per episode and annual total healthcare costs for ambulance attendances for acute chest pain using a large, state-wide, population-based sample in Victoria, Australia. Moreover, we aimed to assess the breakdown of costs according to components of care episodes to identify potential opportunities for improved cost-efficiency, especially among low-risk patients.

METHODS

This was a population-based observational cohort study using ambulance records of attendances for consecutive adult patients with acute chest pain between 1 January 2015 and 30 June 2019 in Victoria, Australia. Ambulance data were linked to the Victorian Emergency Minimum Dataset (VEMD) and the Victorian Admitted Episodes Dataset (VAED) to determine prehospital and

in-hospital management, diagnoses and costs per episode of care. Full details regarding the cohort and linkage processes have been published previously and are included in the online supplemental material.[3 8] Reporting of this study followed Strengthening the Reporting of Observational Studies in Epidemiology reporting guidelines (online supplemental table S1).[9]

Study design

Patients attended by ambulance during the study period were included in the study if paramedics recorded 'chest pain' in the clinical record as the primary reason for attendance or in the secondary survey. To further ensure all undifferentiated patients with chest pain were captured, we additionally included patients with a suspected paramedic diagnosis of ischaemic chest pain, acute coronary syndrome (ACS), acute myocardial infarction, pleuritic pain or angina (although few patients were identified through this strategy further to those identified through the primary reason for attendance and secondary survey definition). Exclusion criteria included traumatic chest pain, interhospital transfers and <18 years of age. Given different funding models and differences in cost reporting, only public hospitals were included in the analysis with ambulance attendances resulting in transport to private hospitals (~6%) excluded from the study.

In Victoria, high-sensitivity troponin assays were available at almost all metropolitan and inner regional centres throughout the study period, with specific assays varying according to hospital. At outer regional centres, contemporary troponin assays were available. Patients brought via ambulance to the emergency department (ED) during the study period classified by receiving clinicians as 'suspected ACS' would undergo standard troponin testing protocols (either serial troponin or single rule-out), depending on patient risk and clinician preference. Non-cardiac investigations would be organised as determined by the treating clinician. No specific state-wide chest pain protocol or pathway exists in Victoria, and therefore each centre would manage patients according to local practices.

Patient demographic data, medical history and attendance details were determined from the ambulance clinical record database. Socioeconomic status was determined using the Index of Relative Socioeconomic Disadvantage (IRSD), which ranks each residential postcode based on household income, unemployment rate, home and motor vehicle ownership, educational level and non-English-speaking background.[10] Conventionally, IRSD percentile ranking data are categorised into quintiles, and the same approach was used in this study. Geographical remoteness was determined by the event postcode using the Accessibility and Remoteness Index of Australia, which uses five categories (metropolitan, inner regional, outer regional, remote and very remote) according to relative access to services. Few locations in Victoria are categorised as 'remote' or 'very remote', and therefore these categories were combined with 'outer regional'.

Discharge diagnoses were defined according to International Statistical Classification of Diseases and Related Health Problems, Tenth Revision, Australian Modification coding as the hospital discharge primary diagnosis if discharged from the hospital or the ED primary diagnosis if discharged from the ED. Coronary angiography, percutaneous coronary intervention (PCI) and coronary artery bypass graft surgery (CABG) rates were determined using Australian Classification for Health Interventions codes as documented in the VAED record, with the specific codes used documented in the online supplemental material.

Cost calculations

Costs were estimated using a 'bottom-up' approach for each component of care with adjustment using the Australian Health Price Index to reflect $A in the 2020–2021 financial year. Ambulance costs were determined from 2021 to 2022 estimates of cost per transport according to event location, emergency status and transport mode, and whether the attendance resulted in transport to hospital or treatment only and referral to another health provider. ED costs were determined using Victoria-specific National Hospital Cost Data Collection estimates for the financial year 2018–2019,[11] which present average costs according to ED episode criteria such as whether the patient was admitted to hospital, was transferred from ED to another hospital, left following or prior to review, or died in the ED.

Hospital admission costs for public hospitals are funded through casemix funding, which is a method of funds allocation according to hospital activities and patients treated. Basic casemix funding involves classifying patients according to diagnosis-related groups, with each like episode funded at the same rate.[12] Refinement of this method has resulted in the development of the weighted inlier equivalent separation (WIES) model, which applies cost weighting to basic casemix funding to account for length of stay. Admission costs were determined by multiplying the episode WIES weight recorded in the VAED dataset by the appropriate WIES price for that financial year.[13] For patients who were transferred to another hospital from the index hospital, costs for the second admission following transfer were estimated using the average overall admission cost for non-transferred episodes according to discharge diagnosis. Further details regarding cost calculations, including estimated prices for each component of care, annual WIES prices, and mean WIES values according to diagnosis, are presented in online supplemental tables S2–S4.

Statistical analysis

Cohort characteristics are summarised as number (%) for categorical data and mean (SD (SD)) for continuous data. Cost data are presented as mean (SD). Temporal trends across the study period for episode costs and total annual costs were assessed using Jonckheere-Terpstra trend test. Total costs per annum were estimated based on the assumption that the diagnosis and cost profile of patients who were transported by ambulance to the hospital but were not able to be linked to VEMD or VAED data would match those of patients who were linked to hospital data. Cost per capita per annum was estimated by dividing the total cost during the study period by the person-years at risk in Victoria, Australia, during the study period. To further understand the breakdown of estimated costs across the spectrum of chest pain presentations, we categorised patients according to the Early Chest pain Admission, Myocardial infarction, and Mortality (ECAMM) risk score,[14]which classifies risk of mortality, myocardial infarction and admission to the hospital for any cause among patients with undifferentiated chest pain and presented mean episode and total annual costs for each category. Risk scores available for suspected ACS (HEART score[15] and EDACS score[16]) were not used, given the cohort represents patients with undifferentiated chest pain. Statistical analysis was performed using StataMP V.17.0.

Patient and public involvement

Patients or the public were not involved in the design, conduct, reporting or dissemination plans of our research.

Table 1 Cohort characteristics

Variable	n (%)
Total	241 627
Age (years), mean (SD)	61.1 (18.7)
18–49	67 364 (27.9)
50–64	61 282 (25.4)
≥65	112 869 (46.7)
Sex	
Women	120 615 (49.9)
Men	120 921 (50.1)
Event location	
Metropolitan	173 453 (72.6)
Inner regional	55 092 (23.0)
Outer regional/remote	10 524 (4.4)
Socioeconomic status	
Lowest	62 226 (28.6)
Low	47 886 (22.0)
Middle	43 025 (19.8)
High	38 678 (17.8)
Highest	26 007 (11.9)
Comorbidities	
Hypertension	98 705 (43.1)
Hyperlipidaemia	70 465 (30.8)
Diabetes mellitus	46 631 (20.4)
Prior coronary disease	76 561 (33.4)
Chronic kidney disease	6913 (3.0)
Peripheral vascular disease	2501 (1.1)
Chronic obstructive pulmonary disease	20 302 (8.9)
Obstructive sleep apnoea	3431 (1.5)
Datasets included	
Ambulance attendance only	14 167 (5.9)
Ambulance, not linked	32 271 (13.4)
Ambulance, VEMD	57 001 (27.2)
Ambulance, VEMD and VAED	138 188 (53.5)

VAED, Victorian Admitted Episodes Dataset; VEMD, Victorian Emergency Minimum Dataset.

RESULTS

From 2 857 760 Triple Zero (000) contacts to Ambulance Victoria during the study period, there were 258 034 unique chest pain episodes attended by ambulance that met inclusion criteria (online supplemental figure S1). Of these, 16 407 cases (6.4%) were transported to private hospitals and were excluded, leaving 241 627 episodes in the primary analysis. Cohort characteristics are presented in table 1; mean age was 61.1 years (SD 18.7); and 50% were women. Event location was metropolitan in 73% of cases, and a higher proportion of included patients resided in areas of lower socioeconomic status (29% lowest quintile vs 12% highest quintile). Ambulance attendance resulted in treatment by ambulance alone without transport to ED in 6% of cases, while 94% were transported to ED. Data included ambulance and VEMD records for 27%; ambulance, VEMD and VAED records for 54%; and 13% were transported to the hospital but were not able to be linked with VEMD or VAED records.

Mean cost per chest pain episode was $6284 (SD $8043) with an estimated overall total annual cost of $337.4 million for patients attended by ambulance for chest pain (table 2). Per-capita costs per year were estimated at $68 for ambulance attendances for chest pain (with a period 22.2 million person-years during the study). Trends in total annual chest pain costs increased from 2015 to 2019 ($310.5 million in 2015 vs $384.5 million in 2019, p for trend=0.014), while mean episode costs remained stable across the study period (p for trend=0.327, figure 1).

Table 2 Episode and annual healthcare costs for acute chest pain presentations according to episode characteristics, admission duration, cardiac procedures and event location

	n	Mean cost (SD)	Total cost per annum ($ million)
Overall	209 356	6284 (8043)	337.44
Episode characteristics			
Ambulance attendance only	14 167	707 (154)	2.59
ED management and discharge	55 175	2346 (846)	33.52
ED management and short stay	61 380	4091 (679)	65.03
ED management and index hospital admission	59 782	9942 (10 651)	153.92
ED management and transfer to other hospital	1474	13 321 (4461)	5.08
ED management, index hospital admission and subsequent transfer to other hospital	17 378	17 257 (15 525)	77.66
Admission duration (hours)*			
0–24	16 469	5501 (2544)	23.46
24–48	10 873	8535 (3266)	24.03
48–72	9374	10 127 (4266)	24.58
>72	40 093	15 794 (15 581)	163.98
Admission location			
Ward only	52 213	9791 (5735)	132.39
Coronary care unit and ward	18 043	12 401 (7229)	57.94
Intensive care unit, <48 hours	3136	19 976 (15 588)	16.22
Intensive care unit, ≥48 hours	2417	43 109 (46 862)	26.98
Procedures*			
Admission without procedure	122 425	7113 (7363)	225.51
Coronary angiography (without revascularisation)	7168	14 027 (12 638)	26.04
Percutaneous coronary intervention	7817	18 155 (12 845)	36.75
Coronary bypass graft surgery	604	64 399 (35 064)	10.07
Pericardiocentesis or pericardial window	79	37 046 (40 730)	0.76
Aortic surgery	96	78 383 (33 650)	1.95
Event location			
Metropolitan	173 453	6142 (8023)	239.28
Inner regional	55 092	6671 (7979)	82.54
Outer regional/remote	10 524	6776 (7059)	16.02

*Excludes short stay.
†Mean and total costs are calculated assuming the 32 271 unlinked episodes that were transported to the hospital had the same diagnoses and cost profile as linked patients. All costs presented in $A adjusted to the 2020/2021 financial year using the Australian Health Price Index.
ED, emergency department.;

Mean costs varied substantially according to episode duration and characteristics, including ambulance attendance alone ($707), ED management and discharge ($2346 without short stay and $4091 with short stay), and hospital admission ($9942 without transfer, $13 321 with ED transfer, and $17 257 with hospital admission and subsequent transfer). Of the total annual costs, ambulance and ED management without admission to the hospital comprised 30% ($101.4 million); admissions to the index hospital comprised 46% ($153.9 million); and transfers to another hospital for admission comprised 25% ($82.7 million). Episodes resulting in admissions to ICU for ≥48 hours ($43 109) were more expensive than shorter ICU admissions of <48 hours ($15

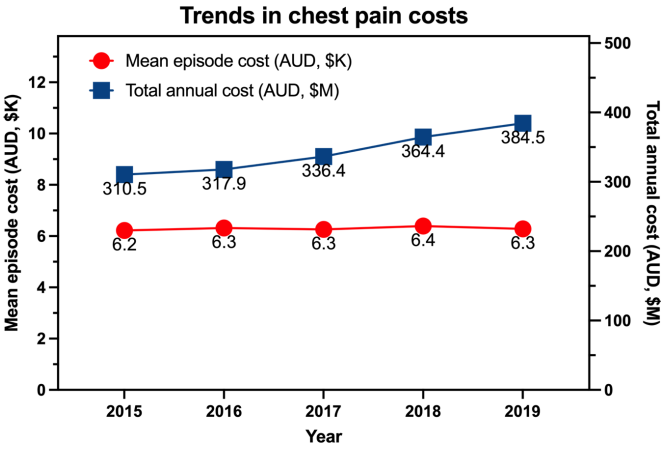

Figure 1 Trends in mean episode and overall annual costs for acute chest pain presentations to ambulance. Estimated direct healthcare costs ($A) of acute chest pain presentations attended by ambulance in Victoria, Australia (2015–2019).

588), CCU admissions ($12 401) or ward only admissions ($9791). Chest pain episodes resulting in admissions with procedures, such as coronary angiography ($14 027), PCI ($18 155), CABG ($64 399), pericardiocentesis ($37 046) and aortic repair ($78 383) were substantially more expensive than admissions without cardiac procedures ($7113). Similarly, chest pain episodes in inner ($6671) or outer ($6776) regional locations had marginally higher costs than metropolitan locations ($6142).

Costs according to specific diagnoses and diagnosis groups are presented in table 3. Patients with a discharge diagnosis of non-specific pain had the lowest mean cost per episode ($3836), but this was the most common diagnosis (48%) accounting for $93.4 million in total annual costs. Cardiovascular diagnoses were, on average, the most expensive (26%, mean cost $11 523) accounting for $148.7 million in total annual costs, followed by respiratory diagnoses (9%; mean cost $8562, annual $37.5 million) and other medical diagnoses (18%; mean cost $6237, annual $55.7 million). Among specific diagnoses, the most expensive conditions included acute aortic syndromes (0.1%; mean cost $49 413, annual $1.92 million), myocarditis (0.1%; mean cost $21 280, annual $0.45 million), valvular conditions (0.2%; mean cost $20 696, annual $1.72 million), ST elevation myocardial infarction (3.0%; mean cost $19 501, annual $29.6 million) and non-ST elevation myocardial infarction (5.4%; mean cost $15 633, annual $42.3 million).

Incremental costs according to episode duration and transfer status stratified by diagnosis group are shown in figure 2. Among patients discharged with a diagnosis of non-specific pain, most were discharged from ED short-stay units (42%, mean cost $3991) with a lower proportion discharged from ED (31%, mean cost $2311). Mean costs increased with admission and longer length of stay across all diagnosis groups, and transfers to other hospitals for admission were associated with higher costs ranging from ~$1000 to ~$3000, depending on diagnosis group.

The ECAMM risk score classified 31.4% of the cohort as very low risk (30-day mortality rate 0.1%, index myocardial infarction rate 2.0%) and 25.8% of the cohort as low risk (30-day mortality rate 0.6%, index myocardial infarction rate 6.0%) with mean episode costs of $3595 and $5394, respectively, and total annual costs of $60.6 million and $74.8 million, respectively (table 4).

Table 3 Diagnosis specific costs for patients presenting to hospital with acute chest pain via ambulance

Diagnosis	n (%)	Mean episode cost (SD)	Total cost per annum* ($ million)
Non-specific pain	93 990 (48.2)	3836 (2391)	93.36
Cardiovascular	49 844 (25.5)	11 523 (12 547)	148.74
ST elevation myocardial infarction	5861 (3.0)	19 501 (16 426)	29.60
Non-ST elevation myocardial infarction	10 455 (5.4)	15 633 (11 542)	42.33
Unstable angina	6404 (3.3)	8280 (6114)	13.73
Stable angina	6723 (3.4)	7806 (11 671)	13.59
Pericarditis	1762 (0.9)	6738 (5278)	3.07
Myocarditis	81 (0.1)	21 280 (71 287)	0.45
Heart failure	4995 (2.6)	10 903 (7045)	14.10
Pulmonary emboli	1395 (0.7)	10 082 (8121)	9.41
AF	5544 (2.8)	6551 (4699)	3.64
Arrhythmia (non-AF)	3688 (1.9)	7392 (12 372)	7.06
Acute aortic syndromes	150 (0.1)	49 413 (42 610)	1.92
Other vascular	795 (0.4)	12 034 (14 436)	2.48
Valvular conditions	320 (0.2)	20 696 (22 741)	1.72
Hypertensive conditions and other cardiac conditions	1671 (0.9)	13 054 (15 957)	5.65
Respiratory	16 889 (8.7)	8562 (9816)	37.45
Upper respiratory tract infection	1723 (0.9)	4789 (4475)	2.14
Lower respiratory tract infection	7580 (3.9)	8941 (11 513)	17.55
Exacerbation of COPD	4618 (2.4)	8921 (6202)	10.67
Asthma	1440 (0.7)	4996 (4359)	1.86
Other respiratory conditions	1528 (0.8)	13 213 (14 145)	5.23
Other medical	34 466 (17.7)	6237 (9567)	55.67
Gastritis	4925 (2.5)	3753 (2631)	4.79
Other gastroenterology	4418 (2.3)	9792 (13 410)	11.20
Rheumatology	3101 (1.6)	9270 (16 446)	7.44
Neoplastic	2144 (1.1)	11 924 (9866)	6.62
Endocrine	1224 (0.6)	8452 (5553)	2.68
Neurological	1242 (0.6)	6933 (18 204)	2.23
Infectious diseases	3940 (2.0)	3848 (3122)	3.93
Mental health	4618 (2.4)	4398 (4023)	5.26
Other conditions	8854 (4.5)	5025 (7326)	11.52

*Total costs per annum assume same diagnoses and costs for patients unable to be linked to hospital data. All costs presented in $A adjusted to the 2020/2021 financial year using the Australian Health Price Index.
AF, atrial fibrillation; COPD, chronic obstructive pulmonary disease; M, million.

DISCUSSION

The current population-based study is one of the largest to describe the economic burden of acute chest pain presentations on health systems. The major findings can be summarised as follows: (1) total annual cost burden for acute chest pain presentations via ambulance increased across the study period, while episode costs remained stable; (2) episode costs varied substantially according to episode characteristics, duration, diagnosis and according to use of interhospital transfers or cardiac procedures; (3) episodes related to cardiac diagnoses were the most expensive, accounting for one quarter of the total presentations but nearly 45% of total annual costs; and (4) although episode mean cost was lower for patients discharged with a diagnosis of

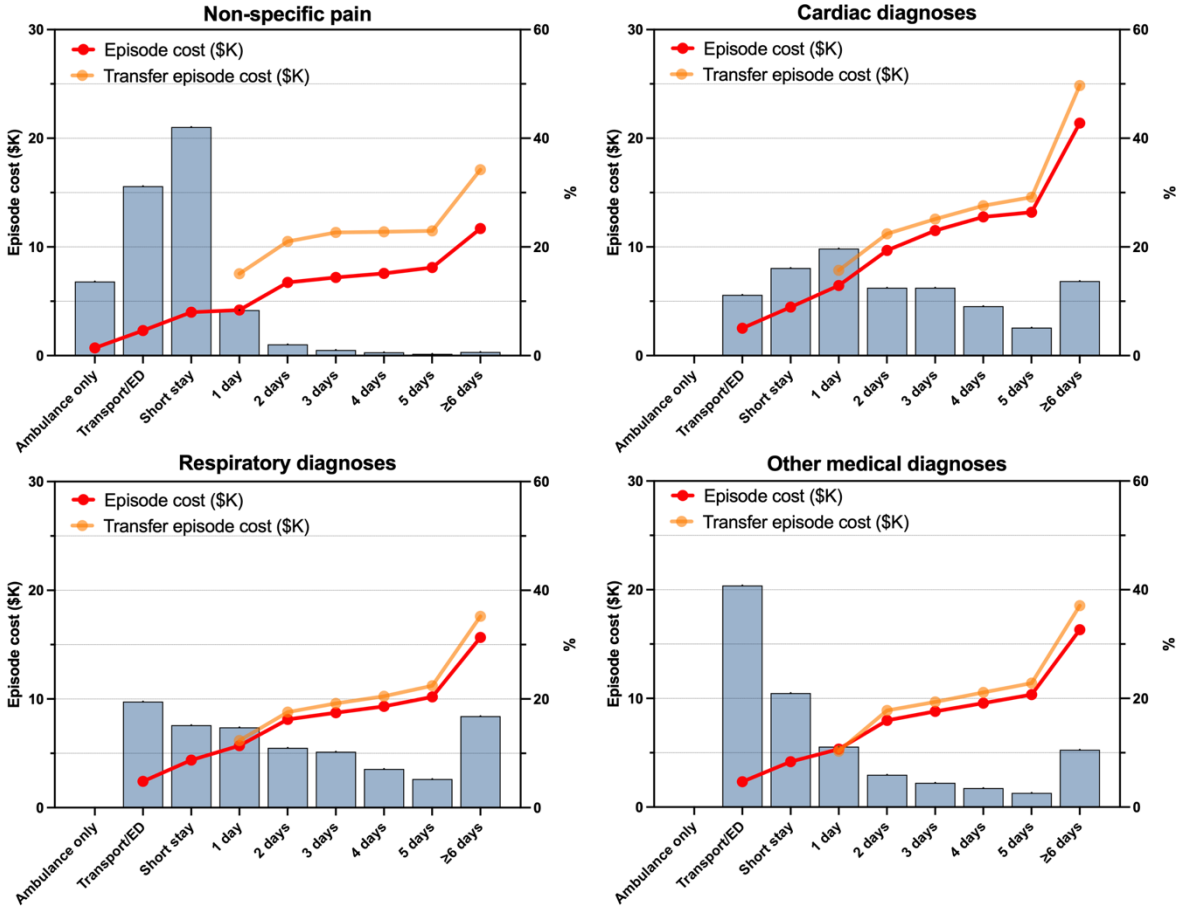

Figure 2 Incremental costs across a presentation episode by diagnosis group. Proportion of patients discharged at each stage shown by blue columns. Mean episode costs ($A) according to episode duration for patients managed at index hospital are shown in red, while mean episode costs for patients transferred from index hospital to subsequent hospital are shown in yellow.

nonspecific pain or classified as low risk, this cohort still represented almost 30% of total annual costs. These data provide a clear breakdown of cost drivers for acute chest pain presentations and highlight presentation characteristics and components of care that might be improved or modified to manage chest pain cohorts more cost-effectively.

Acute chest pain is one of the most common reasons for medical contact accounting for approximately 1 in 10 calls for ambulance assistance.[2 3] Given the spectrum of possible underlying causes, almost all patients are transported to hospital for further detailed assessment aimed at excluding life-threatening conditions such as myocardial infarction, aortic dissection and pulmonary embolism, although approximately 50% of patients can be safely discharged following assessment with no specific diagnosis.[3 5] Previous Australian data have demonstrated that this is an expensive process, and our study suggests that episode costs are comparable overall to other Australian and European estimates.[1 17] However, the incidence of chest pain attendances has been increasing,[3] which has led to a substantial rise in total annual costs for acute chest pain in our region when coupled with population growth. In the USA, mean costs for chest pain presentations to ED are higher, with estimates of US$6325 per episode ($A9193) in 2016.[18] In Victoria, the state-wide annual expenditure on acute health services (including elective admissions) was ~$11 billion in 2018/2019,[19] and thereby acute chest pain presenting via ambulance might be estimated to represent ~3% to 4% of this. Importantly, these are direct costs to the health system and do not account for productivity losses or informal care giving, which have been estimated to account for up to 60% of the cardiovascular disease economic burden.[20–22]

Table 4 Chest pain costs according to pre-hospital risk score using the ECAMM score for undifferentiated chest pain

ECAMM risk score	n (%)	30-day mortality	Index MI	Mean episode cost (SD)	Total cost per annum ($ million)
<50 points	75 814 (31.4)	106 (0.1)	1116 (2.0)	3595 (4340)	60.57
50–69 points	62 398 (25.8)	348 (0.6)	3077 (6.0)	5394 (7061)	74.79
70–89 points	54 289 (22.5)	928 (1.7)	4593 (10.1)	7121 (10201)	85.91
≥90 points	49 126 (20.3)	3054 (6.2)	7530 (17.9)	10 700 (14318)	116.81

The ECAMM score is for undifferentiated chest pain but is not yet prospectively validated. All costs presented in A$ adjusted to the 2020/2021 financial year using the Australian Health Price Index.
MI, myocardial infarction.

For high-cost presentations, identifying components of care that can be modified or excluded without impacting clinical outcomes is likely to be highly valuable. Across the board, length of stay and interhospital transfer use were significant drivers of overall episode costs, and efforts to reduce these without compromising clinical care could result in substantial savings. Chest pain presentations with a subsequent cardiovascular diagnosis were unsurprisingly identified as the most expensive diagnostic group. However, presumably much of this cost is driven by clinically appropriate evidence-based care, where fixed costs, such as revascularisation, may not necessarily provide a promising target for cost reductions. Conversely, the assessment and management of patients classified by the ECAMM score as very low or low risk of MI, death or hospital admission represents ~15% to ~40% of total costs, depending on the cut-off used. Half of the cohort was discharged following assessment with a diagnosis of non-specific pain, which represented almost 30% of the total annual costs for acute chest pain. Certainly, these patients require appropriate workup including exclusion of serious non-cardiac conditions (including CT pulmonary angiography or aortography when indicated) in addition to clinical decision pathways and high-sensitivity troponin protocols when ACS is suspected, but improvements in the efficiency of these protocols represent a promising opportunity for cost reductions. For example, among patients discharged with a diagnosis of non-specific pain, the mean cost of management and discharge from ED was $2311, while the mean cost of management and discharge from short stay was $3991 (a difference of $1680 per episode). Around half of patients who present with acute chest pain via ambulance (~60 000 patients in 2018 in Victoria) are diagnosed with non-specific pain, and of these, ~40% of patients are currently managed through short-stay admissions. For patients who are admitted to short stay to await serial troponin testing, there is potentially a cost saving of up to ~$20 million annually by improving the efficiency of suspected ACS clinical decision pathways (not accounting for patients who present directly to ED), although it should be noted that some patients admitted to short stay in our cohort may be awaiting non-cardiac investigations (such as CT pulmonary angiography or aortography).

There are several promising opportunities for improving chest pain care model efficiency that might reduce costs among low-risk patients. Improvements in troponin assays and clinical decision pathway processes have resulted in substantial reductions in assessment times for patients with suspected ACS over the three decades.[4] A recent trial using the European Society of Cardiology 0/1 hour troponin protocol demonstrated a median assessment time of 2.5 hours, a time frame that might avoid the cost of short-stay admissions identified in the current study.[23] Certainly, in several studies, rapid testing protocols and chest pain decision pathways have been associated with reductions in hospital costs,[24–26] and the introduction of high-sensitivity troponin assays is estimated to have resulted in a 20% reduction in chest pain episode costs on average.[27] In Australia, the implementation of an accelerated decision pathway at 16 hospitals led to savings of $13.5 million during the study period, mostly related to a 13% reduction in hospital admissions.[28] For presentation via ambulance, there has been interest in the utility of point-of-care high-sensitivity troponin devices that could be used while patients are in transit to the hospital, thereby reducing the time required to wait in ED for serial troponin measurements.[29–31] Such devices must maintain high accuracy for the detection of low concentrations of troponin and be robust and reliable in the prehospital environment. Similarly, this approach might be useful in prehospital identification of high-risk patients with positive troponins that can be directly transported to revascularisation capable hospitals, reducing costs associated with interhospital transfers. Some groups have suggested that prehospital risk scoring and troponins might be used to identify patients at very low risk that could be managed by ambulance without transfer to the hospital (an episode cost of $707 in our analysis),[32] although alternate serious diagnoses must also be excluded, and therefore this might be more likely to occur in conjunction with another second medical opinion (eg, virtual EDs), which also has costs.

Limitations

This study has several limitations. Approximately 15% of patients transported to the hospital by ambulance were not able to be linked to emergency or hospital admission datasets. These patients were assumed to have the same diagnostic profile and costs as the linked cohort; however, if differences exist, this might lead to inaccuracies in the cost estimates. A recent analysis of linked versus unlinked patients demonstrated mostly negligible differences between groups.[33] The presented analysis represents the state of Victoria, Australia, and may be generalisable neither to other states of Australia, which have different funding models, nor to other countries. Similarly, troponin assays, protocols for serial sampling, and selection of imaging and angiography were not consistent across the state and could vary from other jurisdictions. Cost estimates for subsequent admissions after transfer from the initial hospital were estimated by the average diagnosis-specific cost for all centres rather than using the subsequent admission WIES values, which could underestimate or overestimate costs among transferred patients. Granular data detailing patients who suffered procedural complications such as major bleeding were not available in the VAED dataset, and therefore the cost impacts of these events could not be assessed. Finally, the study did not estimate costs of productivity loss, informal caregiving or costs of subsequent follow-up, including clinical appointments and outpatient investigations, and represented only the direct healthcare costs from each chest pain episode.

CONCLUSIONS

Total annual healthcare costs for acute chest pain attended by ambulance are increasing, with total annual costs in Victoria, Australia, of ~$337.4 million ($68 per capita per year) during the study period. Low-risk presentations and patients discharged with a final diagnosis of non-specific pain represent 25%–30% of the total annual costs. These data highlight the need to improve the cost-efficiency of chest pain care pathways, especially for low-risk patients.

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Contributors Concept and design of study: DS, KS, LD, EN and ZN; acquisition of data: DS, KS, DK, LD, EN, ZN and SC; analysis of data: LD, EN, SC and EZ; drafting of the manuscript: LD, DS, KS, ZN and EN; revision of the manuscript: JB, SC, DA, MS, JL, AT, DK, LC and EZ; approval of the final manuscript: LD, EN, ZN, JB, SC, DA, MS, JL, AT, DK, KS, DS, LC and EZ. LD and DS accept full responsibility for the finished work and conduct of the study, had access to the data, and controlled the decision to publish. LD and DS act as guarantors.

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SUPPLEMENTAL MATERIAL

Data S1. Supplemental Methods.

I. Dataset linkage processes

Ambulance Victoria is the sole provider of emergency medical services in the state of Victoria, dispatching Advanced Life Support and Intensive Care paramedics to medical emergencies. At the conclusion of each case, paramedics complete an electronic patient care record which captures patient and case details, as well as any management provided. Data from these records are uploaded to and stored within a clinical data warehouse, termed the Victorian Ambulance Clinical Information System (VACIS).

For this study, data linkage was performed to combine electronic patient care record data with key Victorian datasets. These included:

1. Victorian Emergency Minimum Dataset: Victorian Department of Health administrative and clinical data related emergency department (ED) presentations at public hospitals in the state. Data is submitted by individual health services and is then subject to validation checks. For this study, ambulance patient identifiers were matched with Department of Health identifiers using a fuzzy matching process. ED presentations for matched patients were then linked to ambulance cases as follows:

    a. Where the patient was transported to hospital by ambulance, the VEMD arrival time was required to be within one hour of the ambulance ED arrival time.

    b. Where the patient contacted ambulance but was not transported to hospital, the VEMD arrival time was required to be within 48 hours of the emergency call for ambulance. If multiple VEMD records existed within the 48-hour period, the presentation occurring closest in time to the ambulance call was used.

2. Victorian Admitted Episodes Dataset: Victorian Department of Health demographic, clinical and administrative data relating to each admitted episode of care occurring in public and private hospitals, as well as rehabilitation centres, extended care facilities and day procedure centres in the state. For this study, ambulance patient identifiers were matched with Department of Health identifiers using a fuzzy matching process. For matched patients, individual admitted episodes of care occurring up to 48 hours after the emergency ambulance call were linked to the ambulance patient care record data. Where multiple admitted episodes were recorded within the 48 hours, the episode occurring closest in time to the ambulance call was used.

3. Victorian Death Index: Victorian Department of Justice and Community Safety data capturing the date and cause of all deaths in Victoria. For this study, ambulance patient identifiers were matched with Department of Health identifiers using a fuzzy matching process. For matched patients, death records were then linked to all ambulance contacts occurring in the study period.

II. Diagnosis Definitions

The final diagnoses for patients transported to hospital used in Table S1 were categorised using the following International Statistical Classification of Diseases and Related Health Problems, Tenth Revision, Australian Modification (ICD-10-AM) codes (note that these ICD-10-AM codes remain constant across the different ICD-10-AM editions of codes used by hospitals over the study period; i.e. ICD-10-AM: 8th edition in 2014-15, 9th edition in 2015-16 & 2016-17, 10th edition in 2017-18 & 2018-19):

1. Non-ST elevation myocardial infarction: I214, I219
2. Unstable angina: I200
3. Stable angina: I201, I208, I209, I248-I252, I254,I255,I258, I259
4. Pericarditis or myocarditis: I010, I012, I090, I092,I241,I300-I328, I1400-1418, I514
5. Heart failure: I420-I438,I500-I509
6. Atrial fibrillation: I480-I489
7. Other arrhythmia: I441, I442, I456, I458- I461, I469-472, I479, I490-I499
8. Pulmonary embolism: I260, I269
9. Other vascular: I600-I99 excluding codes categorised above

10. Other cardiac: I00-I99 excluding codes categorised above
11. Upper respiratory tract infection: J00-J09,J101,J108,J111,J118,J200-J209,J300-J42
12. Lower respiratory tract infection: J100,J110, J120-J189,J22
13. Exacerbation of COPD: J431-J449, J47-J709,J982,J983
14. Asthma: J450-J46
15. Other respiratory: J00-J998 excluding codes categorised above
16. Gastritis or oesophagitis: K20-K238,K290-K30
17. Other gastrointestinal diagnosis: K000-K938 excluding codes categorised above
18. Infectious diseases: A000-B99
19. Oncological conditions: C000-D899
20. Endocrine disorders: E000-E899
21. Neurological disorders: G000-G998
22. Rheumatological diagnoses: M0000-M99923
23. Mental Health diagnoses: F000-F99
24. Other specialties: H000-H959, L00-L998, N000-Q999, S001-Z999
25. Non-specific chest pain: R000-R99

Cardiac procedure rates were determined according to whether the following Australian Classification for Health Interventions (ACHI) codes were documented in the VAED record for angiography capable centres (note that these ACHI codes remain constant across the different ACHI editions of codes used by hospitals over the study period, i.e. ACHI 8th edition in 2014-15, ACHI 9th edition in 2015-16 & 2016-17; 10th edition in 2017-18 & 2018-19). The following codes were used to derive these variables:

1. Coronary angiography: 3820300, 3820600, 382500, 3821800-3821802.
2. Percutaneous coronary intervention: 3830000, 3830001, 3830600, 3830601, 3830602, 3830603, 3830604, 3830605, 3831200, 3831201, 3831800, 3831801
3. Coronary artery bypass graft surgery: 3849700, 3849701, 3849702, 3849703, 3849704, 3849705, 3849706, 3849707, 3850000, 3850001, 3850002, 3850003, 3850004, 3850005, 3850300, 3850301, 3850302, 3850303, 3850304, 3850305, 9020100, 9020101, 9020102, 9020103

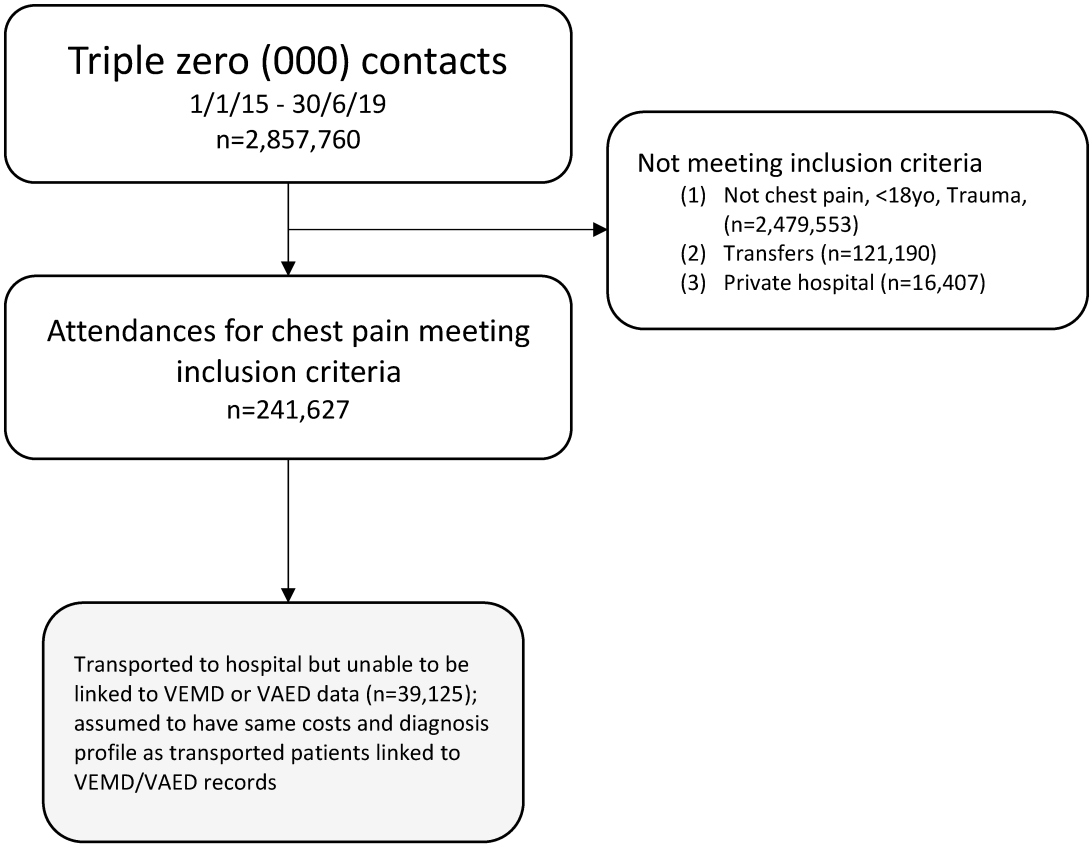

Figure S1. Cohort derivation. VEMD = Victorian Emergency Minimum Dataset, VAED = Victorian Admitted Episodes Dataset

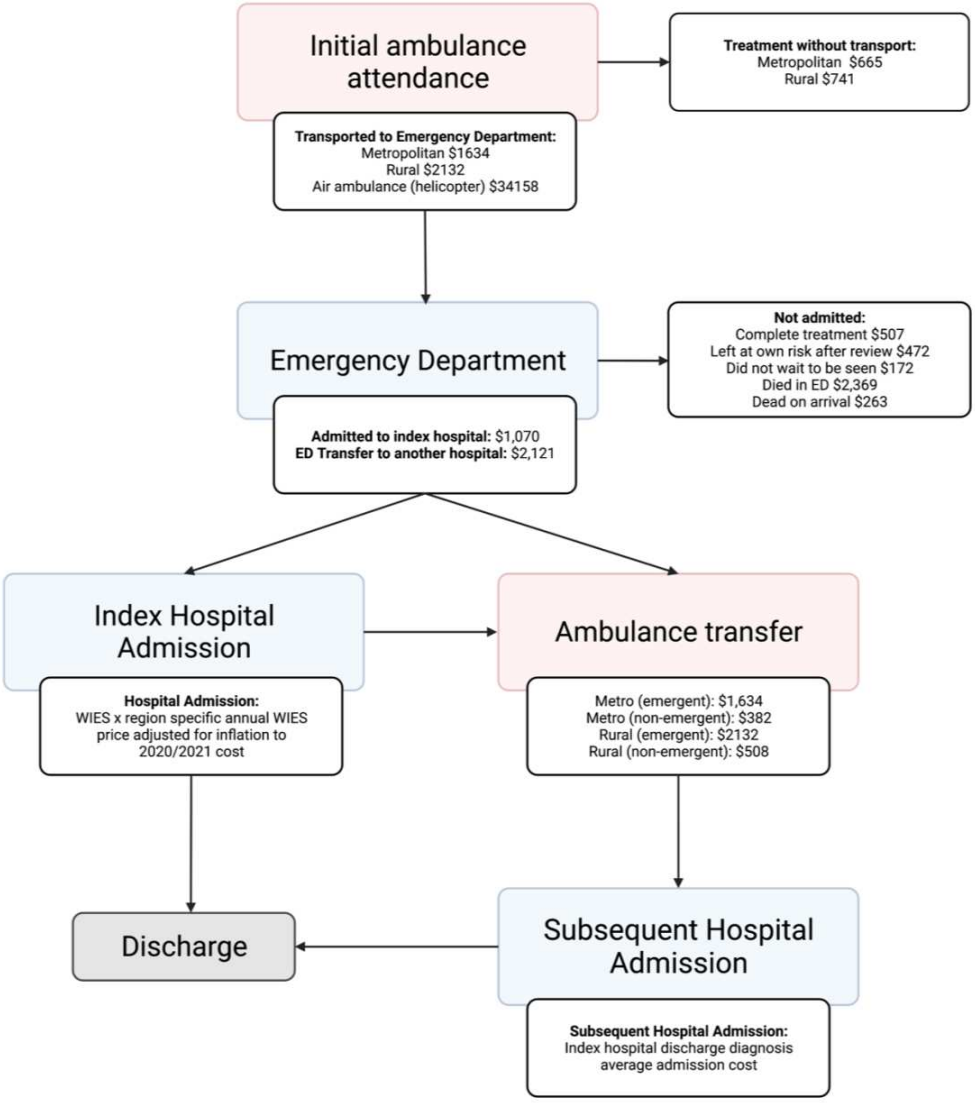

Figure S2. Patient flow during chest pain episode attended via ambulance.

Table S3. STROBE Statement—Checklist of items that should be included in reports of ***cohort studies***

	Item No	Recommendation	Page No
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract (*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	2
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	3
Objectives	3	State specific objectives, including any prespecified hypotheses	3
Methods			
Study design	4	Present key elements of study design early in the paper	3
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	3-4
Participants	6	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up (*b*) For matched studies, give matching criteria and number of exposed and unexposed	4
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	4
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	4-5
Bias	9	Describe any efforts to address potential sources of bias	5
Study size	10	Explain how the study size was arrived at	4-5
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	5-6
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding (*b*) Describe any methods used to examine subgroups and interactions (*c*) Explain how missing data were addressed (*d*) If applicable, explain how loss to follow-up was addressed (*e*) Describe any sensitivity analyses	5-6
Results			
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed (b) Give reasons for non-participation at each stage (c) Consider use of a flow diagram	6
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders (b) Indicate number of participants with missing data for each variable of interest (c) Summarise follow-up time (eg, average and total amount)	6
Outcome data	15*	Report numbers of outcome events or summary measures over time	6-7

Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included (*b*) Report category boundaries when continuous variables were categorized (*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	B/A
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	7-8
Discussion			
Key results	18	Summarise key results with reference to study objectives	8
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	11
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	8-11
Generalisability	21	Discuss the generalisability (external validity) of the study results	11
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	1

*Give information separately for exposed and unexposed groups.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at http://www.strobe-statement.org.

Table S1. Weighted Inlier Equivalent Separation prices used to estimate hospital admission costs with adjustment for inflation to 2020-21 levels.

	WIES Price ($A), original year and adjusted for inflation to 2020-2021 levels						National Health Price Index
Financial year	**Metropolitan**		**Subregional**		**Small rural**		%
	Original	Adjusted	Original	Adjusted	Original	Adjusted	
2014-2015	4385	4816	4459	4898	4678	5138	1.84
2015-2016	4545	4902	4768	5142	4654	5019	1.59
2016-2017	4640	4926	4857	5156	4724	5015	0.84
2017-2018	4732	4982	4978	5241	4795	5048	1.45
2018-2019	4833	5015	5083	5275	4877	5061	2.04
2019-2020							1.70

Data available from Department of Health and Human Services policy and funding guidelines 2014 to 2019, Chapter 3.1.1 Acute admitted services Price Tables.[1] https://www2.health.vic.gov.au/about/policy-and-funding-guidelines

Table S2. Costs for each component of care used to derive each episode cost.

Care component	$A (adjusted to 2020-2021)
Ambulance costs	
Ambulance treatment without transport (metropolitan)	665
Ambulance treatment without transport (rural)	741
Transport to emergency (metropolitan)	1634
Transport to emergency (rural)	2132
Transport to emergency (helicopter)	34158
Emergent transfer (metropolitan)	1634
Non-emergent transfer (metropolitan)	382
Emergent transfer (rural)	2132
Non-emergent transfer (rural)	508
Emergency department costs	
Not admitted – complete treatment	507
Not admitted – left at own risk after review	472
Not admitted – did not wait to be seen	172
Not admitted – died in emergency department	2369
Not admitted – dead on arrival	263
Admitted – index hospital	1070
Admitted – transfer to other hospital	2121

Ambulance costs were estimated from 2022 March margin reporting with adjustment to 2020-21 levels. Emergency department costs were estimated Victoria-specific National Hospital Cost Data Collection (NHCDC) estimates for financial year 2018-19,[2]

Table S4. Weighted Inlier Equivalent Separation (WIES) values for patients admitted to hospital with records available in VAED dataset.

Diagnosis	N (%)	WIES value for VAED portion of episode
Non-specific pain	59685 (43.7)	0.34 (0.47)
Cardiovascular	43010 (31.5)	1.57 (2.39)
ST elevation myocardial infarction	5559 (4.1)	2.83 (2.92)
Non-ST elevation myocardial infarction	9855 (7.2)	1.89 (2.24)
Unstable angina	5461 (4.0)	0.91 (1.16)
Stable angina	5599 (4.1)	0.98 (2.40)
Pericarditis	1395 (1.0)	0.89 (0.88)
Myocarditis	78 (0.1)	3.52 (14.0)
Heart failure	4692 (3.4)	1.42 (1.26)
Pulmonary emboli	1304 (1.0)	1.34 (1.50)
Atrial fibrillation	4585 (3.4)	0.74 (0.77)
Arrhythmia (non-AF)	2.087 (1.5)	1.44 (2.96)
Acute aortic syndromes	150 (0.1)	7.93 (8.14)
Other vascular	635 (0.5)	1.53 (2.79)
Valvular conditions	320 (0.2)	3.17 (4.58)
Hypertensive conditions & other cardiac	1290 (0.9)	2.32 (3.39)
Respiratory	13443 (9.8)	1.24 (2.02)
Upper respiratory tract infection	1022 (0.8)	0.63 (0.87)
Lower respiratory tract infection	6047 (4.4)	1.30 (2.45)
Exacerbation of COPD	4093 (3.0)	1.19 (1.08)
Asthma	988 (0.7)	0.62 (0.80)
Other respiratory	1293 (1.0)	2.14 (2.85)
Other medical	20576 (15.1)	1.07 (2.25)
Gastritis	2644 (1.9)	0.40 (0.54)
Other gastroenterology	3746 (2.7)	1.48 (2.83)
Rheumatology	2127 (1.6)	1.75 (3.74)
Neoplastic	2020 (1.5)	1.61 (1.84)
Endocrine	1061 (0.8)	1.13 (0.92)
Neurological	919 (0.7)	0.97 (4.06)
Infectious diseases	1742 (1.3)	0.52 (0.67)
Mental health	2183 (1.6)	0.69 (0.89)
Other conditions	4134 (3.0)	0.93 (1.83)

N=136714 (no available WIES data for 1474 patients transferred from ED to alternate hospital without admission to index hospital) *total costs per annum assume same diagnoses and costs for patients unable to be linked to hospital data. All costs presented in Australian dollars ($A) adjusted to the 2020/21 financial year using the Australian Health Price Index. COPD = chronic obstructive pulmonary disease, AF = atrial fibrillation, M = millions, SD = standard deviation

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