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Review Article

Costs of Australian intensive care: A systematic review

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ABSTRACT

Objective: Intensive care unit (ICU) cost estimates are critical to achieving healthcare system efficiency and sustainability. We aimed to review the published literature describing ICU costs in Australia.
Design: A systematic review was conducted to identify studies that estimated the cost of ICU care in Australia. Studies conducted in specific patient cohorts or on specific treatments were excluded.
Data sources: Relevant studies were sourced from a previously published review (1970–2016), a systematic search of MEDLINE and EMBASE (2016–5 May 2023), and reference checking.
Review methods: A tool was developed to assess study quality and risk of bias (maximum score 57/57). Total and component costs were tabulated and indexed to 2022 Australian Dollars. Costing methodologies and study quality assessments were summarised.
Results: Six costing studies met the inclusion criteria. Study quality scores were low (15/41 to 35/47). Most studies were conducted only in tertiary metropolitan public ICUs; sample sizes ranged from 100 to 10,204 patients. One study used data collected within the past 10 years. Mean daily ICU costs ranged from $966 to $5381 and mean total ICU admission costs $4888 to $14,606. Three studies used a top-down costing approach, deriving cost estimates from budget reports. The other three studies used both bottom-up and top-down costing approaches. Bottom-up approaches collected individual patient resource use.
Conclusions: Available ICU cost estimates are largely outdated and lack granular data. Future research is needed to estimate ICU costs that better reflect current practice and patient complexity and to determine the best methods for generating these estimates.

1. Introduction

Global demand and costs for intensive care services are rapidly increasing due, in part, to technological and treatment advances, ageing populations and rising rates of co-morbid chronic illness.[1–4] The Australian healthcare system has experienced similar trends. In Australia, there has been an increasing number of intensive care unit (ICU) admissions and patient bed days.[5] To keep pace with demand, staffing rates have also increased.[5] Given the resource-intensive nature of ICUs, it is essential to understand the financial costs of providing intensive care. Cost data helps monitor healthcare system efficiency and inform resource allocation decisions in the face of competing demands.[6,7] In addition to how ICU and hospital resource data are valued, what data are collected and how data are measured can have a considerable impact on resource allocation decisions and, ultimately, decisions regarding the implementation of interventions.[8] Without accurate data on the costs of delivering ICU care and robust costing methodologies, health economic evaluations cannot appropriately inform implementation decisions.[4]

Understanding costs is also required to ensure ICUs are appropriately reimbursed for the resources used. Australia's public hospitals are funded by the federal, state and territory governments

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through activity-based funding (i.e. based on the number and type of patients treated). The Independent Health and Aged Care Pricing Authority sets the "nationally efficient price", or price paid for each unit of activity. The ICU adjustment is calculated by the estimated ICU cost per hour and the reported number of whole ICU hours. It does not account for variation in case mix or treatment within the ICU (i.e. the ICU adjustment is consistent across patient groups).[9] Alternative funding models would be based on clinical needs (e.g. organ supports) and treatments provided, as seen in the National Health Service in the United Kingdom,[10] or based on patient outcomes. Revising funding models would require high-quality data to inform current and future costs.

Despite the importance of health economics, there has been little published on the costs of intensive care in Australia. An earlier review of costing studies from Australia identified only five reports that were published between 1976 and 2010.[11] A contemporary review of ICU costs is required to help inform healthcare policy and research priorities. The aim of this systematic review was to review the published literature describing ICU costs in Australia, with the objectives to i) quantify the cost estimates and ii) describe how the costs were estimated.

2. Methods

We conducted a systematic review of the literature to identify studies that estimated the costs of ICU care in Australia. We followed the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) 2020[12] (Appendix 1) and prospectively registered the study in PROSPERO (CRD42023424109). We included a previously published review,[11] which reviewed the literature from 1970 until 2016, and a de-novo systematic search in MEDLINE and EMBASE from 2016 to present (5 May 2023). Main MeSH terms and keywords included costs and cost analysis, critical care and intensive care units and Australian states and territories. Reference lists of relevant reviews were also searched. A complete search strategy is presented in Appendix 2.

Publications reporting the costs of ICU care were included, with the exclusion of publications reporting costs of ICU in specific patient cohorts (Table 1). We excluded studies that reported the cost or cost-effectiveness of ICU treatments, as the focus of this review was to quantify and describe the costs of delivering overall ICU care. Two independent reviewers screened titles and abstracts, then full-text studies. Disagreements were resolved through discussion until a consensus was reached. Studies underwent data extraction by two independent reviewers with disagreements resolved by a third independent reviewer. Basic study characteristics, costing perspective, currency and year of cost collection, in-hospital and ICU mortality, ICU length of stay, total cost per day and cost per admission, categories of costs collected and any subgroup analyses were extracted from each study (Appendix 3).

Table 1
Inclusion and exclusion criteria.

Inclusion Criteria	Exclusion criteria
1. Costing study 2. Conducted in the intensive care unit setting (including adult, paediatric and neonatal facilities) 3. Conducted in Australia 4. Published in English language	1. Does not report overall total intensive care unit costs 2. Study conducted in a specific patient cohort or on a specific treatment 3. Includes the intensive care unit but costs for the intensive care unit are not reported separately 4. Not an observational study (e.g. systematic review) 5. Not peer-reviewed (e.g. conference abstract)

A template was developed prior to data extraction to assess study quality and risk of bias. This incorporated recommendations from the Consolidated Health Economic Evaluation Reporting Standards, Drummond Checklist for economic evaluations, and governmental reporting guidelines.[13–17] Quality items from these resources were compiled.[13–17] The research team comprising health economists and clinicians met to discuss the items relevant to costing studies and the scope of each item (i.e. 'Guidance for reporting'). The quality and risk of bias template was refined until a consensus was reached. Study quality was assessed by two independent reviewers using the developed template (Appendix 4), with disagreements resolved by a third independent reviewer. Studies received one point for each item they reported and an additional point if their reporting of each method item was 'appropriate' (i.e. aligned with the 'Guidance for reporting'). Quality assessment results were tabulated, and studies were given a composite quality assessment score based on the number of possible points (maximum score 57/57). A higher quality assessment score indicates the study is of better quality and has a lower risk of bias.

The total and component costs reported across the included studies were tabulated. Costing methodologies for each component cost were categorised as top-down or bottom-up. Top-down costing approaches included accessing compiled hospital records and bottom-up approaches included collecting and valuing individual patients' resource use.[8] Reported costs were then indexed to 2022 Australian Dollars (AUD) values using the consumer price index,[18] and component costs were categorised to allow for comparison across studies.

3. Results

The systematic review from 2016 to present identified 710 citations after the removal of duplicates, with 17 citations undergoing full-text review (see Fig. 1). With the inclusion of four costing studies identified in the previously published review (studies published prior to 2016),[11] a total of seven manuscripts representing six costing studies met our eligibility criteria. Included studies were published between 1977 and 2019 based on data collected between 1976 and 2014 (Table 2).

3.1. Study quality

Overall certainty of evidence is low, as study quality was generally poor (range: 15/41 to 35/47). All studies provided relevant background information, clearly stated study objectives and presented an appropriate time horizon for the study. Although most studies (n = 4) clearly identified and listed resource items used in their respective analyses, a majority (n = 4) did not report the methods and tools used to identify resource items, assumptions regarding resource use measurement and a clear description of the method and source of unit cost data. Furthermore, most (n = 5) studies did not describe the classification of cost items, sensitivity analyses, sources of cost estimates and conflicts of interest. No studies reported on prices for marketable items, identification of joint costs and sample size calculation. The complete quality assessments and scores are presented in Appendix 7.

3.2. Costs of providing intensive care in Australia

All studies reported daily ICU costs (Table 3). The mean daily ICU cost of adult or combined adult and paediatric ICU ranged from $966 to $5381.[19,21–25] Two studies also reported total ICU admission costs, which ranged from $4888 to $14,606.[20,24] Three studies estimated costs using only a top-down approach,[19,23,25] and three

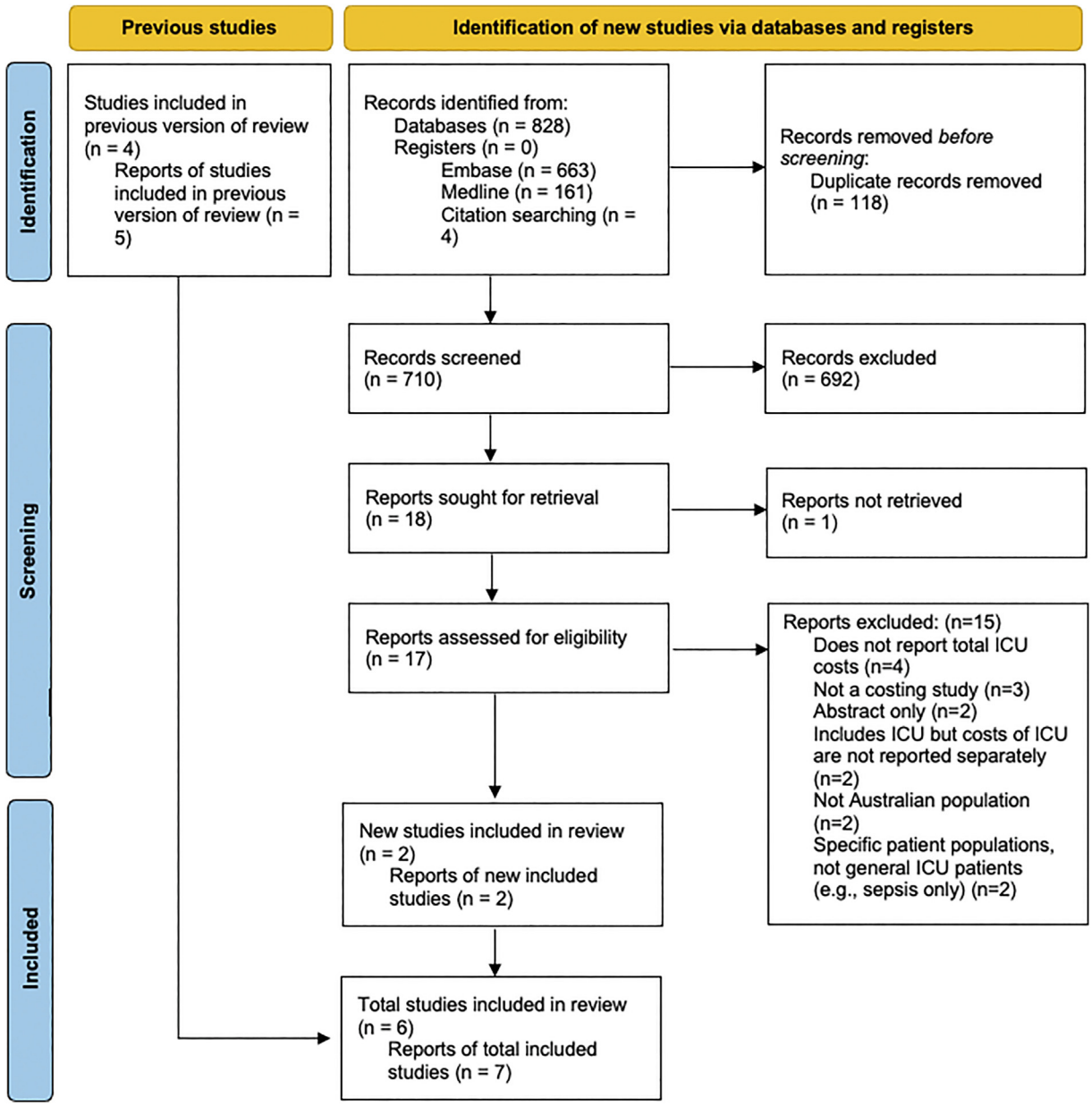

Fig. 1. Preferred Reporting Items for Systematic Reviews and Meta-analyses (PRISMA) flow diagram.

studies incorporated a combination of top-down and bottom-up approaches[20–22,24] (Table 2).

Component costs were categorised into staffing, diagnostic services, consumables, equipment and overheads (Appendix 5 & 6). The complete list of costing components, approaches, measures and results for adult and combined adult and paediatric ICUs are presented in Appendix 5.

3.3. Staffing

Staffing costs were reported in all studies and included nursing, medical, allied health, clerical, physiotherapy and non-clinical support staff. Three studies used a top-down approach by reviewing annual reports to collect staffing costs.[19,23,25] Staffing costs were then allocated to patients based on ICU length of stay, number of patient-days reported by the ICU or number of reported available beds. Two studies used a mix of top-down and bottom-up approaches for collecting and allocating staffing costs to patients.[20–22] The remaining study utilised a bottom-up approach by calculating the staffing costs for each subject based on the time spent with each subject and average wages of the various categories of health professionals (medical, nursing and physiotherapists).[24] Staffing costs were estimated to account for 54% of the total ICU costs in studies using a bottom-up approach[20,24] and 69–82% of the total ICU costs in studies using a top-down approach[19,23,25] (Fig. 2).

3.4. Diagnostic services and consumables

Diagnostic services and consumables were reported in all studies. Four studies used top-down approaches to determine the costs of diagnostic services and consumables.[19,23–25] Three of the four studies reviewed annual reports and allocated costs to patients based on ICU length of stay, number of patient-days reported by the ICU or number of reported available beds.[19,23,25] The other study

Table 2
Characteristics of costing studies in Australian intensive care units (n = 6 studies).

Author(s) (Year) (Citation)	Study design	Study setting	Study setting	Study population	Number of patients, n	Site (n of sites if multi-centre)	Costing approach	Year(s) of cost collection
Rechner and Lipman (2005)[19]	Retrospective cohort study	Surgical ICU; Medical ICU	Tertiary; Metropolitan; Public	Adult	1615	Single centre	Top-down	2002/3
Moran et al. (2004)[20]	Retrospective cohort study	Surgical ICU; Medical ICU	Tertiary; Metropolitan; Public	Adult	1333	Multi-centre (n = 3)	Top-down & Bottom-up	1991
McKinley (1995, 1996)[21,22]	Prospective cohort study	Mixed ICU; Surgical ICU; Medical ICU	Private; Public	Adult and paediatric	13,694	Multi-centre (n = 34)	Top-down & Bottom-up	1994
McCleave et al. (1977)[23]	Retrospective cohort study	Surgical ICU; Medical ICU	Tertiary; Metropolitan; Public	Adult	843	Single centre	Top-down	1976
Slatyer et al. (1986)[24]	Prospective cohort study	Mixed ICU; Surgical ICU; Medical ICU	Tertiary; Metropolitan; Public	Combined adult/ paediatric	100	Single centre	Top-down & Bottom-up	1983
Hicks et al. (2019)[25]	Cross-sectional	Surgical ICU; Medical ICU	Tertiary; Non-tertiary; Metropolitan; Regional; Rural; Private; Public	Combined adult/ paediatric	–	Multi-centre (n = 36)	Top-down	2013/14

Note: ICU = intensive care unit; Types of costing approach could include top-down (e.g. accessing compiled hospital records) and/or bottom-up approaches (e.g. collecting and valuing individual patients' resource use).

estimated the costs of diagnostic tests using Medical Benefits Schedule records to determine the proportion of total admission costs attributed to diagnostic tests.[24] Two studies collected actual costs of medical and surgical supplies, pathology tests, radiology costs and drugs (e.g. parenterally administered fluids) according to patient usage.[20–22] Diagnostic services included radiology, pathology, pharmacy and laboratory services. The total cost of diagnostic services represented 10%–25% of the total ICU costs.[19,20,23,24] Consumables included drugs, blood, medical and surgical supplies, intravenous therapy, oxygen and fluids. The total cost of consumables represented 16%–20% of the total ICU costs and intravenous therapies represented 1–2%.[19,24,25]

3.5. Equipment and hospital overheads

Costs of equipment and other hospital overheads were reported by five studies.[19–24] Four studies used a top-down approach by ascertaining the total ICU operational costs via hospital budget records or case mix classification scheme and allocated costs to patients based on ICU length of stay.[19,20,23,24] One study calculated individual patient cost data per day for biomedical engineering and equipment maintenance, central sterile supply department, capital depreciation, goods and services and hospital overheads.[21,22] Total equipment costs, including capital equipment maintenance and depreciation and biomedical engineering, represented 2% of the total ICU costs.[19] Mean costs for overheads, such as central sterile supply department, goods and services and light and power, represented approximately 19% of the total ICU costs.[20]

Table 3
Patient outcomes and intensive care cost per day or cost per admission reported in Australian intensive care unit costing studies.

Author(s) (Publication Year)	ICU length of stay (days) Mean (SD)	ICU cost per day (2022 AUD) Mean (SD)	ICU cost per admission (2022 AUD) Mean (SD)
Rechner and Lipman (2005)[19]	3.69 (range 0.5–77)	$4423	–
Moran et al. (2004)[20]	3.9 (6.1)	–	$14,606
McKinley (1995, 1996)[21,22]	Public- 3.1 Private 2.5 PICU – 2.59	Public- $3443 Private- $2496	–
McCleave et al. (1977)[23]	Surgical- 4.1 Medical- 2.7	$1951	–
Slatyer et al. (1986)[24]	3.4	$966 (500)	$4888 (9637)
Hicks et al. (2019)[25]	–	$5381 (1423)	–

Note: ICU = intensive care unit; PICU = paediatric intensive care unit; SD = Standard deviation. Cost data are indexed to 2022 Australian Dollars (AUD) values using the consumer price index.

4. Discussion

Accurate ICU cost estimates are critical to achieving healthcare system efficiency and sustainability. This systematic review aimed to review the published literature describing ICU costs in Australia, with the objectives to i) quantify the cost estimates and ii) describe how the costs were estimated. We identified seven manuscripts representing six costing studies conducted in Australian ICUs. Overall certainty of evidence is low, as study quality was generally poor. Most studies lacked a thorough description of how resource items were identified and measured and how costs were estimated and analysed. Only one study included data collected within the past 10 years and the remaining studies used data collected between 1983 and 2003. The mean daily ICU cost (2022 AUD) of adult or combined adult and paediatric ICU ranged from $966 to $5381 and total ICU admission costs ranged from $4888 to $14,606. Three studies used a top-down costing approach, and the other three used a combination of top-down and bottom-up costing approaches.

Large variations in reported costs may be due to wide data collection periods and differences in costing approaches. For example, diagnostic testing comprised 25% of total ICU costs in 1983 and 11% in 1991 and staffing costs ranged from 54% of total ICU costs in 1983 and 1991 to 82% in 2013.[19,20,23–25] A review of ICU costing studies in OECD countries obtained similar results to the current review.[26] Eighteen studies were identified, with wide variations in ICU costs observed across patient groups, among centres and within countries.[26] Changes in disease mechanisms, multi-organ manifestations and patient-case mix observed in ICUs over time have given rise to technological advances and organisational transformations.[27] Critical care—and healthcare systems more broadly—has responded to rapidly increasing demand and costs for services by implementing new technologies and organisational practices.[28] The redistribution of costs to keep pace with demand and respond to patients' needs is likely reflected in the observed changes in proportional costs over time. Although staffing costs were the dominant contributor to the total ICU costs across all included studies, variations in staffing costs were also observed by costing approach. Staffing costs were estimated to account for 69–82% in studies using a top-down approach[19,23,25] and 54% of the total ICU costs in studies using a bottom-up approach.[20,24] The most recent data on staffing

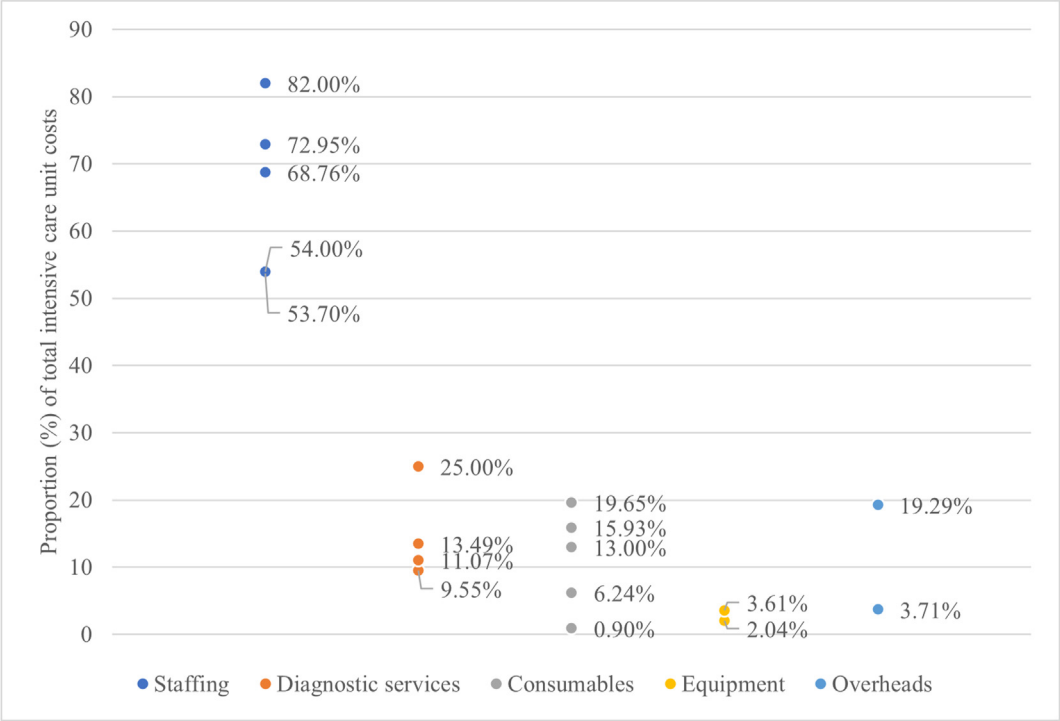

Fig. 2. Estimates of proportional intensive care unit costs in Australia, reported in six costing studies.[19–25]

costs in Australian ICUs were collected in 2014,[25] but only aggregate costs were collected and allocated to patients based on ICU length of stay and available beds (i.e. top-down approach). The most recent staffing cost data in Australian ICUs collecting and valuing individual patients' resource use (i.e. bottom-up approach) were collected in 1991.[20] Simply inflating historical cost data neglects to account for changes in healthcare technology, practice and patient complexity over time.[27] The generalisability of available data is also questionable, as most studies (n = 4) were conducted only in tertiary metropolitan public ICUs and one study reported paediatric ICU costs.[21,22] Therefore, the actual cost of providing intensive care in Australia today and variations by available technologies, patient complexity and organisational context remain unknown. This is despite healthcare expenditure increasing,[29] ICU accounting for a substantial component of the health budget[25] and the need for healthcare reform to ensure its sustainability.

Given the pivotal role but expense of ICU care, optimising resource utilisation while ensuring cost-effectiveness and patient safety is critical to long-term sustainability. The 2023–24 national ICU reimbursement rate in Australia is $264 per hour.[9] If we exclude the outlier ($966) in the review which excluded equipment and overhead costs, the mean daily ICU cost ranged from $1951 to $5381 or $81 to $224 per hour. However, costs are historical and conducted predominantly in tertiary metropolitan public ICUs, so it is unknown whether current reimbursement covers costs. Accurate cost estimates are essential to effectively inform the allocation of limited resources across competing demands. Top-down costing approaches assume every ICU-day costs the same regardless of disease, treatments provided, complexity and costs in other budgets. Bottom-up approaches can be very complex, labour intensive and require multiple data sources. There is, therefore, a need for new approaches to costing ICU care in Australia. A mechanism to use routinely reported administrative health data—which most Australian ICUs already collect through centralised electronic medical records—to accurately cost services based on resource allocation (e.g. organ supports received) would enable better estimation and prediction of the costs of ICU services.[11] The widespread implementation of electronic medical records in ICUs may now enable greater insights into the resources provided for each ICU admission and enable more detailed bottom-up costs to be determined. Furthermore, the standard inclusion of cost analysis in clinical research would be of great benefit for research into the cost-effectiveness of alternative practices.[4] A collaborative effort between researchers and policymakers is crucial to refining the methods of cost determination, updating cost estimates and investigating variation in ICU costs.

4.1. Strengths and limitations

This systematic review was prospectively registered, employed a systematic search of academic databases and utilised two independent reviewers to identify relevant studies for inclusion. A tool for assessing quality and bias of costing studies was developed, and the analysis was reported following PRISMA guidelines to ensure transparency and replicability.[12] We have included the tool should other groups choose to use it (Appendix 4). The generally low quality of evidence, small number of studies and historical data limit the generalisability of the results presented. Furthermore, half (n = 3) of the studies were single-centre studies.[19,23,24] We, therefore, avoided making cost comparisons between different types of ICUs, given the different approaches to estimate costs and the uncertain validity of each approach. We recommend future costing studies improve reporting on the methods used for resource use measurement, classification of cost items, dealing with uncertainties, sources of cost estimates and conflicts of interests.

5. Conclusion

Prior studies identify Australian ICU care as costly. However, these studies have predominantly relied on historical data and a top-down costing approach, lacking granular information on cost drivers. This systematic review identified six studies reporting costs

in Australian ICUs. Included studies were of generally low quality and lacked representation outside of tertiary metropolitan public ICUs. The most recent data were from 10 years ago. There is a need for ICU cost estimates to be contemporaneous and reflect heterogeneity of patients and the treatments provided. Further research is required to understand how to best determine ICU costs.

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Data availability statement

No new data were created.

Conflict of interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

CRediT authorship contribution statement

Alayna Carrandi: Conceptualization, Methodology, Formal analysis, Investigation, Data Curation, Writing - Original Draft, Writing - Review & Editing, Project administration. **Cheelim Liew**: Formal analysis, Investigation, Data Curation, Writing - Review & Editing. **Matthew J Maiden**: Conceptualization, Methodology, Writing - Review & Editing, Supervision. **Edward Litton**: Conceptualization, Methodology, Writing - Review & Editing, Supervision. **Colman Taylor**: Conceptualization, Methodology, Writing - Review & Editing, Supervision. **Kelly Thompson**: Conceptualization, Methodology, Writing - Review & Editing, Supervision. **Alisa Higgins**: Conceptualization, Methodology, Writing - Review & Editing, Supervision.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ccrj.2024.03.003.

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