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Review Paper

The evolution of Australian intensive care and its related costs: A narrative review

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ABSTRACT

Objective: To conduct a narrative review on the evolution of intensive care and the cost of intensive care services in Australia.
Review method: A narrative review using a search of online medical databases and grey literature with keyword verification via Delphi-technique.
Data sources: Using Medical Subject Headings and keywords (intensive care, critical care, mechanical ventilation, renal replacement therapy, extracorporeal membrane oxygenation, monitoring, staffing, cost, cost analysis) we searched MEDLINE, PubMed, CINAHL, Embase, Google and Google Scholar.
Results: The search yielded 30 articles from which we provide a narrative synthesis on the evolving intensive care practice in relation to key service elements and therapies. For the review of costs, we found five relevant publications and noted significant variation in methods used to cost ICU. Notwithstanding the limitations of the methods used to cost all publications reported staffing as the primary cost driver, representing up to 71% of costs.
Conclusion: Intensive care is a highly specialised medical field, which has developed rapidly and plays an increasingly important role in the provision of hospital care. Despite the increasing importance of the specialty and the known resource intensity there is a paucity of data on the cost of providing this service. In Australia, staffing costs consistently represent the majority of costs associated with operating an ICU. This finding should be interpreted cautiously given the variation of methods used to cost ICU services and the limited number of available studies. Developing standardised methods to consistently estimate ICU costs which can be incorporated in research into the cost-effectiveness of alternate practice is an important step to ensuring cost-effective care.

1. Background

Intensive care is a medical specialty dedicated to the management of patients with life-threatening illness.[1] In 1961, the first two intensive care units (ICUs) opened in Australia. By 2007 there were 149 ICUs providing 1881 available beds, 1318 ventilator beds and staffed by a total of 6578 full time registered nurses and 477 full time intensive care specialists.[2]

Intensive care is an integral component of modern healthcare[3] providing advanced technologies which require the skills of highly specialised healthcare professionals.[4] The demand for ICU services and the cost of providing these services has increased rapidly[5] due to an ageing population and the introduction of new technologies which have enabled long-term multi-organ support.[6,7] Epidemiological studies have shown that most hospital deaths occur in the ICU[1] and that only a small proportion (4%) of patients admitted

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have an advanced care directive in place.[2] In light of this, research evaluating the cost and sustainability of intensive care is important.

Our objective was to provide a narrative review of the literature to understand and describe the evolution of intensive care services from inception to present (1970s–2016) and the estimated costs of providing ICU services in Australia. We report on the development of key service elements (such as invasive therapies, monitoring, and staffing) that may have contributed to the increasing costs of providing intensive care services over time as well as the reported costs of providing ICU services in Australia.

2. Review method & data sources

To identify articles that reported on the development of ICU in Australia we undertook a broad search of the literature via multiple online sources using Cochrane's recommended guidelines for conducting narrative synthesis.[8] MEDLINE, PubMed, CINAHL and Embase were searched using Medical Subject Headings (MeSH) including; Intensive Care, Critical Care, Australia and 'History, 20th Century.' We then consulted an informal Delphi panel of experienced ICU clinicians and academics to determine the main service elements of intensive care. This enabled us to develop specific keywords to separately insert into the original MeSH search string (excluding the Australia and/or History, 20th Century MeSH to increase yield of search). Our keywords included; mechanical ventilation; renal replacement therapy (RRT) and extracorporeal membrane oxygenation (ECMO); monitoring; nursing staff and medical staff. Titles and abstracts of articles were reviewed and included if they reported a comprehensive or historical perspective on the development of ICU in Australia (Fig. 1).

To describe the actual costs of ICU services over time we undertook a separate search of both MEDLINE and the grey literature (Google and Google Scholar) to identify articles evaluating the cost of intensive care services and interventions using MeSH terms of; Intensive Care and/or Critical Care and 'Australia' with economic focussed MeSH terms; Costs and Cost Analysis.

Finally, we reviewed the reference lists of relevant articles and the grey literature to find additional material not found through the other search methods.

3. Results

Fig. 1 provides an overview of the search results on the evolution of intensive care with a total of 30 articles describing the development of intensive care considered relevant for discussion in this narrative review. From the included 30 articles on the evolution of intensive care, we describe modern intensive care services and the development over time of the key service elements (invasive therapies, monitoring and staffing) of ICUs in Australia. We also report a summary of the five from nine relevant costing studies, estimating the cost of receiving care in an Australian ICU and compare costs over time.

3.1. Key ICU service elements

Highly invasive therapies have enabled ICU clinicians to support physiological life in the absence of independently functioning vital organs. This may have considerable implications for the economics of care.[1] This literature search and Delphi panel identified several therapies which are fundamental to supporting life in the ICU and potentially contribute to the increasing costs of ICU services.

3.1.1. Mechanical ventilation

Positive pressure ventilation facilitated the development of the intensive care specialty.[9] In the last 60 years, ventilator use has increased due to the establishment of multidisciplinary ICUs, the ability to obtain point-of-care pathology such as arterial blood gases, and rapidly advancing engineering technology.[9] Developed in the 1950s, the first ventilators required patients to receive pharmacological paralysing and sedative agents to enable effective ventilation.[10] Significant developments have occurred since this time including; the introduction of Positive End Expiratory Pressure (PEEP), the invention of pressure support ventilation in the 1980s which revolutionised ventilator weaning, and the introduction of safety alarms in the 1990s.[9] Technological developments have made mechanical ventilators safe and sophisticated devices able to synchronise spontaneous patient breaths and mechanical breaths without the requirement for pharmacological intervention.[9,11] Despite many advances in modern Australian ICU's, less than half of all patients receive mechanical ventilation during their admission[12] implying a trend away from mechanical ventilation as an absolute requirement for admission to the ICU.

3.1.2. Continuous renal replacement therapy

Renal replacement therapy (RRT) was developed for patients with chronic renal failure but was adapted by the intensive care specialty in the 1970s to enable continuous RRT to be carried out on critically ill patients. With the early devices, complications were common due to the requirement for arterial puncture and adequate blood pressure to tolerate the therapy.[13] In the 1980s, the invention of double lumen catheters enabled delivery of RRT via venepuncture and the introduction of peristaltic pumps enabled large volumes of blood to be removed, cleaned and replaced to the patient in a continuous cycle. Both advances significantly improved the safety of administering RRT in the ICU.[13] In 2001, the incidence of severe acute renal failure requiring RRT in Australia and New Zealand was approximately 8 per 100,000 adults per year.[14] Despite these technological advances to improve the efficacy of RRT delivery in ICU, the mortality and morbidity burden for patients that require RRT in the ICU remains high.[13,14]

3.1.3. Extracorporeal membrane oxygenation

Extracorporeal membrane oxygenation (ECMO) evolved from the discipline of cardiac surgery in the 1950s and is considered the most invasive and resource intensive therapy available in modern intensive care.[15] ECMO provides cardiac and/or pulmonary support as an alternative means of respiratory gas exchange to aid oxygenation and ventilation to allow severely injured lungs time to rest and heal.[15,16] Use of ECMO in ICU was not widely adopted throughout the 1970s and 1980s due to mortality rates of greater than 90%.[15] In the last two decades advances in technology to increase circuit life and the introduction of veno-venous ECMO have made delivery safer.[15,17] Targeted research on the use of ECMO in ICU patients has demonstrated better chances of survival[15] and in 2009 during the H1N1 epidemic ECMO was successfully used to prevent mortality in greater than 80% of cases.[18] Despite improvements in safety and efficacy, ECMO is infrequently used, generally initiated as a rescue therapy and commenced on suitable candidates when all other therapeutic measures have been exhausted.[15]

3.1.4. Monitoring

The availability of continuous physiological monitoring and patient observation by skilled nursing staff is a core capability provided in all ICUs.[19] The first invasive monitoring devices available in ICU were central venous catheters (1960s) and pulmonary artery catheters (1970s).[13] These devices stimulated the speciality by providing insight into haemodynamics at the bedside.[13] Monitoring capabilities have continued to evolve since the beginnings of ICU with the College of Intensive Care Medicine (CICM) Minimum Standards for Intensive Care (2011) providing the best insight into current bedside monitoring requirements.[19] Monitoring devices

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