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ORIGINAL RESEARCH

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The efficiency, timeliness, health outcomes and cost-effectiveness of a new aeromedical retrieval model in Central Australia: A pre- and post-implementation observational study

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Abstract

Objective: To assess timeliness, efficiency, health outcomes and cost-effectiveness of the 2018 redesigned Central Australian aeromedical retrieval model.

Design: Pre- and postimplementation observational study of all patients receiving telehealth consultations from remote medical practitioners (RMPs) or Medical Retrieval and Consultation Centre (MRaCC) physicians between 1/1/2015 and 29/2/2020. Descriptive and inferential statistics measuring system efficiency, timeliness, health outcomes and incremental cost-effectiveness.

Findings: There were 9%–10% reductions in rates of total aeromedical retrievals, emergency department admissions and hospitalisations postimplementation, all p-values < 0.001. Usage rates for total hospital bed days and ICU hours were 17% lower (both $p < 0.001$). After adjusting for periodicity (12% fewer retrievals on weekends), each postimplementation year, there were 0.7 fewer retrievals/day ($p = 0.002$). The mean time from initial consultation to aeromedical departure declined by 18 minutes post-implementation (115 vs. 97 min, $p = 0.007$). The hazard of death within 365 days was nonsignificant (0.912, 95% CI 0.743–1.120). Postimplementation, it cost \$302 more per hospital admission and \$3051 more per year of life saved, with a 75% probability of cost-effectiveness. These costs excluded estimated savings of \$744,528/year in reduced hospitalisations and the substantial social and out-of-pocket costs to patients and their families associated with temporary relocation to Alice Springs.

Conclusion: Central Australia's new critical care consultant-led aeromedical retrieval model is more efficient, is dispatched faster and is more cost-effective.

These findings are highly relevant to other remote regions in Australia and internationally that have comparable GP-led retrieval services.

KEYWORDS
emergency medicine, health service delivery, models of care, remote health

1 | INTRODUCTION

Central Australia is geographically large and sparsely populated and a high proportion of the population are Aboriginal and Torres Strait Islander peoples, who have poorer health outcomes and a higher need for health services than their metropolitan and non-Indigenous counterparts.[1] Delivering efficient, timely and cost-effective primary health and emergency care to this population is challenging and demands evidence-based, contextually relevant, high quality services delivered by a fit-for-purpose health workforce.[2–5] The aeromedical retrieval system in Central Australia comprises the following components: NT Department of Health (NT DoH) employed doctors who receive referrals, provide clinical advice using telehealth and coordinate retrievals as needed; flight doctors employed by NT DoH who are responsible for direct patient care during aeromedical transportation; St Johns Ambulance Australia (SJAA) staff who transport patients via road; and the Royal Flying Doctors Service (RFDS) staff who provide fixed wing aeromedical transport.

A recent innovation was the re-design of the referral and coordination component of the aeromedical retrieval model, which was implemented on 12 February 2018. The previous model featured Remote Medical Practitioners (RMPs) – doctors holding qualifications as general practitioners (GPs) – rostered round the clock to receive and prioritise all calls for medical assistance for patients located more than 150 kilometres from Alice Springs. RMPs managed primary care presentations and liaised with Alice Springs Hospital Emergency Department (ED) consultants to co-ordinate aeromedical retrievals for more acutely unwell patients.

The model re-design comprised a new Medical Retrieval and Consultation Centre (MRaCC) and a separate Remote Outreach Consultation Centre (ROCC). RMPs working in ROCC accept referrals of patients with primary care problems that can be managed in the community during usual business hours. MRaCC consultants – doctors with advanced critical care skills (Rural Generalists with advanced emergency medicine, ICU, or anaesthetic skills or medical specialists within these disciplines) – accept all acute care referrals and all referrals outside of usual business hours. Remote clinicians can calculate a Remote Early Warning Score, as described in the Central Australian Rural Practitioners Association (CARPA) standard treatment manual, to assess risk and determine whether to refer to MRaCC or ROCC. The re-designed model, which comprises a 60% overall increase in rostered doctor-hours (from approximately 188 h/week to 302 h/week), aims to improve timeliness, efficiency and effectiveness by directly connecting remote health staff with doctors with the most appropriate skills to manage each patient's presenting conditions. At the time when MRaCC/ROCC commenced, there was scant published peer-reviewed evidence about optimal design of aeromedical retrieval models in geographically remote

What this study adds?

- The new remote area retrieval model in which physicians with advanced critical care skills respond directly to emergencies and physicians with primary care skills respond to primary care presentations is associated with improved system efficiencies, including 9% reductions in aeromedical retrieval rates, 10% reductions in hospitalisation rates and 17% lower usage rates for total hospital bed days and ICU hours.
- Timeliness, measured as the mean time from initial consultation to "wheels up", is 18 min less under the new aeromedical retrieval model (115 versus 97 min, $p=0.007$); however, the mean time from consultation to Emergency Department arrival is not statistically significantly different pre- versus post-implementation.
- Savings related to reduced hospitalisation rates associated with the new retrieval model are estimated to be $744 528/year. This amount offsets the additional costs associated with the new model. Our modelling, which excluded these potential savings, shows that the new model is cost-effective, as it is unlikely to cost more than $90 020/year of life saved, which is still well under the Australian willingness to pay threshold of $202 942 for a year of life.

What is already known on this subject

- There is scant published evidence about processes and structures associated with optimal effectiveness of remote retrieval services.
- While a range of system factors have been associated with improved retrieval efficiency, timeliness, and health outcomes, little is known about how these are associated with the skills of the health professional providing telehealth responses to emergency calls.
- A clear need has been identified for further empirical research using rigorous evaluation methods, particularly of the costs, effectiveness and efficiency of different retrieval models and strategies.

settings such as Central Australia.[6] While some structural and process features of aeromedical retrieval model structures are known to be associated with timeliness, there is a lack of evidence about how the professional training of the person managing the emergency call is associated with aeromedical retrieval timeliness or with system efficiency. Further, while there is some evidence about associations between patient health outcomes and system characteristics such as a single point of contact for all emergency services[7] and training of first respondents,[8] little is known about how and whether the professional training of the person responding to referrals is associated with health outcomes.

In view of these identified limitations of the extant literature, this pre- and post-implementation retrospective observational study aims to assess the impact of the new remote Central Australian MRaCC/ROCC aeromedical retrieval model on system efficiency, timeliness, patient health outcomes and cost-effectiveness.

2 | METHODS

2.1 | Design

This study uses a one-group pre- and post-implementation design.

2.2 | Setting

The re-designed aeromedical retrieval service covers the Central Australia region, which is approximately 900 000 square kilometres (km) in area and accepts referrals of patients with acute conditions from remote communities located at least 150 km and up to 1000 km from Alice Springs, including the cross-border areas in South Australia and Western Australia. Referrals of patients with subacute and non-acute conditions are mainly from within NT.

2.3 | Intervention

The key features of the intervention include: separation of emergency and primary care streams; dedicated resource of doctors with advanced critical care skills for emergency cases who had access to hospital and primary care information systems; dedicated resource of doctors with primary health care for primary health care cases during usual business hours; increase in overall number of doctor hours to support other cadres of remote health professionals (e.g. Remote Area Nurses, Aboriginal Health Practitioners), including with their upskilling.

2.4 | Data collection

Data sources comprise routinely collected Central Australian Health Service (CAHS) retrievals, admitted inpatients, emergency department presentations, primary care consultations and financial data as well as Royal Flying Doctor Service (RFDS) Central Operations and St John Ambulance Australia (SJAA) NT retrievals data. Study data – for all persons using these services – were available for the period between 1 January 2015 and 31 December 2020, inclusive. The pre-MRaCC/ROCC study period was 1 January 2015 to 11 February 2018 (1138 days), inclusive. The post-implementation period was from 12 February 2018 to 29 February 2020 (748 days), inclusive, in order to exclude COVID-19 impacts.

2.5 | Analysis

System efficiency is measured using numbers and rates of consultation, aeromedical retrievals, aeromedical retrievals excluding repatriations and interhospital transfers (excluding patient pick up locations of Alice Springs, Tennant Creek, Darwin, Adelaide, Broken Hill, Port Augusta, and Mt Isa), road ambulance retrievals, ED presentations, total hospital admissions, potentially preventable hospital admissions, total hospital bed days and total intensive care unit (ICU) hours. Mean length of hospital stay and mean ICU hours per hospital admission are also calculated. Potentially preventable hospitalisations, an indicator of primary health care (PHC) service effectiveness, are consistent with Australian Institute of Health and Welfare definitions.[9] These hospitalisations could potentially have been prevented by optimal PHC management at an earlier stage (noting that the term does not mean that the patient did not require hospitalisation). Euclidean distances between aeromedical departure and destination sites are calculated in kilometres using Google maps.

An interrupted time series analysis of daily total RFDS retrievals is undertaken, fitting an autoregressive integrated moving average (ARIMA) model (that is, regressing the number of daily retrievals on the daily number of retrievals or the error terms at previous time points).[10] Parameters of the ARIMA model were determined by using autocorrelation function graphs and partial autocorrelation correlograms as per the Box Jenkins method.[11]

Pre- and post-implementation comparison of evacuees' health outcomes are undertaken using the Kaplan Meier method of survival analysis to calculate the crude probabilities of survival at 365 days.[12] The log-rank test is used to test differences in survival. Proportional hazard ratios are estimated using a Cox model with 95% confidence intervals.[13]

Pre- and post-implementation comparisons of timeliness of aeromedical retrievals are undertaken by calculating mean and median times from date and time of initial consultation requesting retrieval until aeromedical departure from base, initial request to ED arrival, and from initial request to hospital admission.

Pre- and post-implementation comparisons of system efficiency use the following descriptive statistics:

- Total number of consultations,
- Number of emergency consultations,
- Number and rate of:
    - Consultations resulting in aeromedical retrieval,
    - Consultations resulting in retrieval by road,
    - Retrievals requiring hospital admission,
    - Retrievals requiring hospital admission for potentially preventable conditions,
- Total and mean hospital bed days per hospital admission, and
- Total and mean ICU hours per hospital admission.

Economic analyses calculate two separate incremental cost-effectiveness ratios ($ICER_1$ and $ICER_2$ below) comparing costs and effectiveness of the two service models in terms of years of life lost (YLLs) and ICU hours usage.

$$ICER_2 = \frac{\text{Mean costs per admitted patient}_{\text{MRACC/ROCC model}} - \text{Mean costs per admitted patient}_{\text{RMP-led model}}}{\text{Mean ICU hours per admitted patient}_{\text{MRACC/ROCC model}} - \text{Mean ICU hours per admitted patient}_{\text{RMP-led model}}}$$

$$ICER_1 = \frac{\text{Mean costs per admitted patient}_{\text{MRACC/ROCC model}} - \text{Mean costs per admitted patient}_{\text{RMP-led model}}}{\text{Mean YLLs per admitted patient}_{\text{MRACC/ROCC model}} - \text{Mean YLLs per admitted patient}_{\text{RMP-led model}}}$$

In these analyses changes in direct costs pre- and post-implementation are calculated by examining expenditure incurred in the NT DoH Central Australian cost centres used for retrieval costs. Costs captured by these cost centres include medical consultant salaries and operational expenses. Costs related to remote staff overtime are not captured; nor are costs related to the fixed-term contract between RFDS and CAHS for provision of retrieval services, as these fixed costs are incurred irrespective of the number of retrievals and interhospital transports undertaken. Changes in other costs incurred (e.g. various consumables) by remote clinics or patients as a result of the model change also are not captured. Standard costing methods (with health inflation of all health costs to the 2019–2020 financial year) are used to estimate health costs covering PHC, patient transport and hospitalisation costs based on the Australian Refined Diagnostic Related Groups (AR- DRGs) national cost weight times the NT prices each year in 2019–2020 constant Australian dollars.[14]

Effectiveness measures are YLLs and ICU hours per admitted patient. YLLs rates are used as they are accessible and have been previously reported in the peer-reviewed literature pertaining to the remote Australian context, and are known to be acceptable proxy measures for health system effectiveness.[15] YLLs are calculated based on the standard life expectancy table from the national burden of disease and injury study (if death occurred).[16] Uncertainty of the incremental cost-effectiveness ratios is assessed using 2000 bootstrap replicates which are used to plot cost-effectiveness planes (mean differences in the cost and effect pairs) and to create cost-effectiveness acceptability curves (probability that the new MRaCC/ROCC model is cost effective). A willingness-to-pay threshold of $202 942 is used as the benchmark price for a YLL.[17] A willingness-to-pay threshold of $244 is used as the benchmark price for an ICU hour, which is taken from a national ICU costing study.[18] The national study includes a high proportion of tertiary ICUs, which have somewhat lower costs per patient-day than is likely to be the case in ICUs in other types of hospitals, including in regional hospitals such as Alice Springs Hospital, because of economies of scale.

Analyses are undertaken using Stata 16 (StataCorp, College Station, TX, USA). A level of statistical significance of $\alpha = 0.05$ is used throughout.

The research is approved by the Central Australian Human Research Ethics Committee (Ref: CA-19-3320).

3 | RESULTS

3.1 | System efficiency

Overall, there is no statistically significant difference in consultation rates between models ($p = 0.4921$) (Table 1). Nor is there any statistically significant difference in road ambulance retrieval rates pre- and post-implementation ($p = 0.3576$). Most SJAA road ambulance retrievals are interfacility transfers (76%) with a minority (15%) being primary transport of patients to hospital. An even smaller proportion (8%) are transfers with a medical escort. For pickups outside of Alice Springs and Tennant Creek, road ambulances travel a median Euclidean distance of 118 km from their dispatch base (interquartile range (IQR) 115–193).

The pre-implementation aeromedical retrieval rate (excluding repatriations and interhospital transfers) was 10% higher (4.6/day) than the post-implementation rate (4.2/day) ($p < 0.001$). Most aeromedical retrievals (85%) are from NT, with a minority from South Australia (13%) and Western Australia (2%). Excluding patient repatriations from Alice Springs back to community and interhospital transfers (e.g. from Tennant Creek, Darwin or interstate), patient pickup locations are a median Euclidean distance of 314 km from Alice Springs (IQR 214-380).

Moving Average ARIMA (0, 0, 7) is the best ARIMA model for these retrieval data. The time series analyses detected 7-day periodicity in the daily retrieval data, with approximately 12% fewer retrievals than average on Saturdays and Sundays. The ARIMA model that fits the data best adjusts for this periodicity and for first order autocorrelation between errors (residuals) over time, using parameters for p, d and q of 0, 0 and 7, respectively (Figure 1). The interrupted ARIMA (0, 0, 7) model regresses the daily retrieval count variable on an indicator of pre- versus post-implementation and on a variable measuring the number of years since the intervention started. A statistically significant ($p = 0.002$) negatively sloped ramp was detected post-implementation indicating that each year there are approximately 0.7 fewer retrievals/day than in the previous year.

Presentation rates to ED are 5.3/day and 4.7/day pre- and post-implementation, respectively ($p < 0.0001$), or approximately 10% lower post-implementation ($p < 0.0001$). Total hospital admission rates, similarly, are 10% lower post implementation ($p < 0.0001$). Potentially preventable hospitalisations are 19% lower post-implementation ($p < 0.0001$).

Hospital bed day rates were 23.1 bed days/study day pre-implementation and 19.1 post-implementation ($p < 0.0001$). The mean lengths of stay per hospital admission were 4.7 and 4.3 days, pre- and post-implementation, respectively ($p = 0.0663$).

Total ICU hours per study day are approximately 17% lower post-implementation ($p < 0.0001$). The mean ICU hours per hospital admission, however, is not statistically significantly different pre- compared with post-implementation ($p = 0.3352$), although this latter statistic does not take into account the lower hospital admission rate post-implementation.

3.2 | Timeliness

3.2.1 | Time from initial consultation until RFDS departure from base

Pre-implementation mean time from initial consultation to aeromedical departure was 115 min (SD 84) and the median time was 86 min (IQR 56-158). The equivalent mean and median times post-implementation are 97 min (SD 72) and 69 min (IQR 54-122), respectively. The difference in means of 18 min is statistically significant ($p = 0.0066$).

3.2.2 | Time to ED arrival

The pre-implementation mean time from consultation to ED arrival was 9.1 h (SD 8.4) and the median time was 7.0 h (IQR 5.6-9.4). The equivalent times post-implementation are 7.5 h (SD 8.0) and 6.4 h (IQR 5.0-10.0), respectively. The difference in means of 1.6 h is not statistically significant ($p = 0.0566$).

3.2.3 | Time to hospital admission

Testing for differences in the time from initial MRaCC consultation to hospital admission pre- compared to post-implementation reveals a difference in means of 1.7 h which lacks statistical significance ($p = 0.2165$).

TABLE 1 Summary of consultation, retrieval and hospital activity by patients consulted by telehealth RMPs or MRaCC consultants, 2015–2020.

	1 January 2015–11 February 2018 RMP-led model (PRE)	12 February 2018–29 February 2020 MRaCC/ ROCC model (post)	Incidence rate difference	Incidence rate ratio	*p* Value
Days of data captured	1138	748			
Efficiency					
Total consultations	198 321	130 036			
Total consultation rate/day	174.3	173.8	−0.4	1.00	0.4921
Total aeromedical retrievals[a]	8633	5140			
Total aeromedical retrieval rate/day[a]	7.6	6.9	−0.7	0.91	<0.0001
Aeromedical retrievals excluding repatriations and interhospital transfers[b]	5266	3142			
Aeromedical retrievals rate/day excluding repatriations and interhospital transfers[b]	4.6	4.2	−0.4	0.91	<0.0001
Road ambulance retrievals[c]	539	377			
Road ambulance retrieval rate/day[c]	0.5	0.5	0.0	1.06	0.3576
Emergency Department presentations[d]	6002	3532			
Emergency Department presentation rate/day[d]	5.3	4.7	−0.6	0.90	<0.0001
Total hospital admissions[d]	5580	3301			
Total hospital admission rate/day[d]	4.9	4.4	−0.5	0.90	<0.0001
Potentially preventable hospital admissions[d]	769	407			
Potentially preventable hospital admission rate/day[d]	0.7	0.5	−0.1	0.81	<0.0001
Total hospital bed days[d]	26 280	14 306			
Hospital bed day rate/day[d]	23.1	19.1	−4.0	0.83	<0.0001
Mean (SD) hospital length of stay (days)[d]	4.7 (0.14)	4.33 (0.13)			0.0663
Total ICU hours	23 844	13 045			
Total ICU hours rate/day	21.0	17.4	−3.5	0.83	<0.0001
Mean (SD) ICU hours/hospital admission	4.1 (0.43)	3.18 (0.51)			0.3352
Timeliness					
Mean (SD) time from consultation to aeromedical departure from base (minutes)	115 (84)	97 (72)			0.0066
Median (IQR) time from consultation to aeromedical departure from base (minutes)	86 (56, 158)	69 (54, 122)			0.0130
Mean (SD) time from consultation to ED arrival (hours)	9.1 (8.4)	7.5 (8.0)			0.0566
Median (IQR) time from consultation to ED arrival (hours)[d]	7.0 (5.6, 9.4)	6.4 (5.0, 10.0)			0.1030

TABLE 1 (Continued)

	1 January 2015–11 February 2018 RMP-led model (PRE)	12 February 2018–29 February 2020 MRaCC/ ROCC model (post)	Incidence rate difference	Incidence rate ratio	*p* Value
Mean (SD) time from consultation to hospital admission (hours)[d,e]	11.3 (12.3)	9.6 (6.9)			0.2165
Median (IQR) time from consultation to hospital admission (hours)[d]	9.0 (7.2, 12.1)	7.9 (5.8, 11.2)			0.0630
Health outcomes					
Number of deaths within 365 days[d]	123	79			
Total deaths within 365 days (rate/ day)	0.108	0.106	−0.002	0.97	0.8768
Mean Years of Life Lost (per patient for patients who died within 365 days of consultation and retrieval)[d]	0.96 (0.78, 1.12)	0.86 (0.66, 1.05)			0.4572

[a]Total aeromedical retrievals include patient repatriations (e.g. from Alice Springs to community) and interhospital transfers (e.g. from interstate to Alice Springs and from Tennant Creek or Darwin to Alice Springs).

[b]Aeromedical retrievals excluding repatriations do not include aeromedical flights leaving from Alice Springs Airport or those arriving from Adelaide, Port Augusta, Broken Hill, Darwin, Tennant Creek or Mt Isa.

[c]Road ambulance retrievals excluding retrievals of patients within the same town (Tennant Creek or Alice Springs). RMP, Remote Medical Practitioner; MRaCC/ROCC, Medical Retrieval and Consultation Centre/Remote Outreach Consultation Centre.

[d]Calculated using merged retrieval and hospitalisation data sets.

[e]Calculated using logarithmic transformation.

3.3 | Health outcomes

Figure 2 compares one-year survival probabilities pre- and post-implementation. In total, 123 patients died within 365 days of initial consultation pre-implementation and 79 post-implementation. The Cox proportional hazard ratio is 0.912 (95%CI 0.743–1.120), with a log rank test of 0.3777 ($p = 0.380$), indicating that there is insufficient evidence to reject the null hypothesis that the hazard of patient death at any time within the first year following initial consultation is no different between models. However, survival probabilities from approximately 8.5 months following initial consultation are significantly higher for patients consulted under the MRaCC/ROCC model. See also effectiveness measures related to rates of ICU usage and years of life lost, reported below.

3.4 | Cost-effectiveness

The average costs per retrieval pre- and post-implementation are $1147 and $1449, respectively, a difference of $302 more per retrieval post-implementation ($p < 0.0001$).

Using 2019/2020 data on average cost/hospital separation in NT of $4158,[14] the estimated reduction in total hospital admission rates observed post-implementation can be expected to save NT DoH $744 528/year in hospitalisation costs. Note that these hospitalisation-related savings are not included in the following cost-effectiveness analyses.

3.4.1 | Analysis 1: Effectiveness measured by ICU hours per hospitalised patient

Table 2 details the estimated costs, ICU hours per hospitalised patient and the incremental cost-effectiveness ratio pre- and post-implementation. The new MRaCC/ROCC model is associated with 0.36 fewer ICU hours per hospitalisation, a difference that is not statistically significant ($p = 0.6072$). Overall, the point estimate of the incremental cost-effectiveness ratio is that the new model costs an extra $845 per ICU hour per patient admitted to hospital. This statistic not only has a wide confidence interval but is more than the Australian willingness-to-pay threshold of $244 per ICU hour (see additional files 1 and 2 for cost-effectiveness plane and cost-effectiveness acceptability curve, respectively). We therefore cannot be confident that the newly implemented MRaCC/ROCC model is cost-effective in terms of cost of ICU hours per admitted patient).[18]

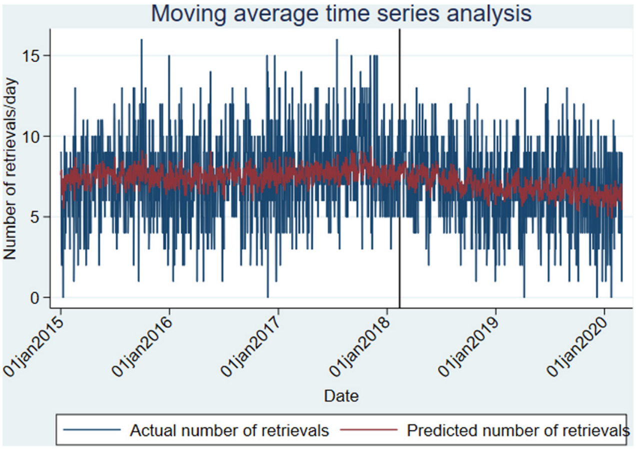

FIGURE 1 Interrupted time series (ARIMA) model of total aeromedical retrievals per day, Central Australia, Jan 2015 to Feb 2020.

3.4.2 | Analysis 2: Effectiveness measured by years of life lost

The pre-implementation average YLLs per retrieved and admitted patient was 0.96, compared to 0.86 post-implementation ($p=0.4572$). Table 3 details the estimated costs and YLLs per patient pre- and post-implementation. The new MRaCC/ROCC model has an estimated incremental cost-effectiveness ratio of −$3051 per YLL. While the 95% confidence interval is wide (see additional file 3 for cost-effectiveness plane), its lower limit, obtained using simulations, is $90 020 which is significantly less than the Australian willingness to pay threshold for a Year of Life saved ($202 942). As shown in the cost acceptability curve (Figure 3), there is an approximately 75% probability that the post-implementation model is cost-effective

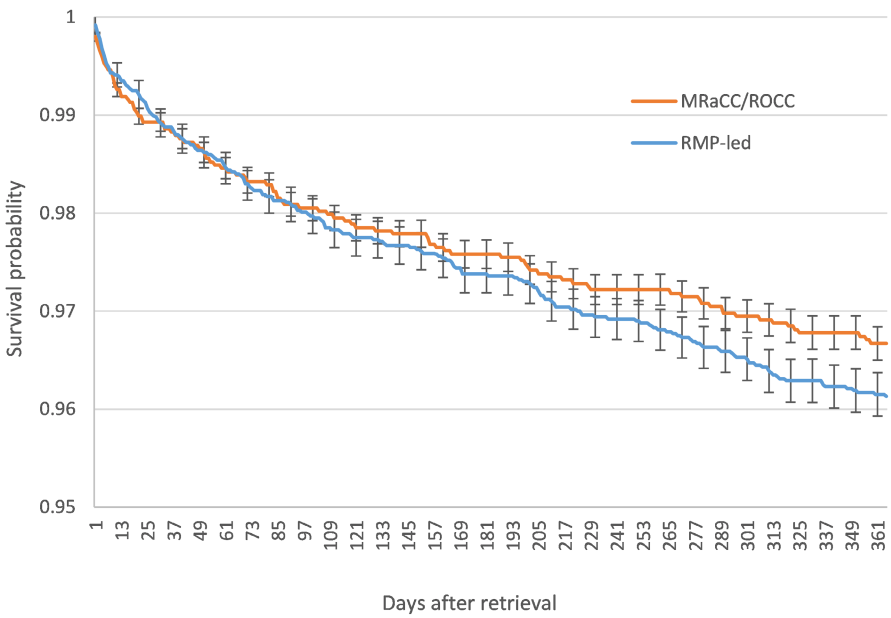

FIGURE 2 Kaplan–Meier 1-year survival and failure estimates, the new MRaCC/ROCC model versus old RMP-led model.

TABLE 2 Average health costs and ICU hours per hospitalised patient and incremental cost-effectiveness ratio pre- versus post-implementation.

	RMP-led model	MRaCC/ROCC model	Pooled data
n (hospitalisations)[a]	4629	3333	7962
ICU hours per hospitalisation[b]	3.81	3.45	0.36
95%CI or *p*-value	(2.94–4.68)	(2.39–4.52)	$p=0.6072$
Average incremental cost/hospitalisation	$1147	$1449	-$302
95%CI or *p*-value	($1145–$1149)	($1446–$1452)	$p<0.0001$
ICER			−$845
95%CI, *p*-value	(−$150 235 to $148545), $p=0.9910$		

[a]Number of hospitalisations vary from the total shown in Table 1 due to mismatches occurring as a result of inability to perfectly link the different data sets required for this analysis (e.g. RFDS with inpatient admissions data).

[b]ICU hours per hospitalisation are based on all hospitalisations (includes those with zero ICU hours (about 90% of those presenting to ED), those admitted to ICU (4%) and excludes those discharged from the emergency department without hospital admission (6%)).

TABLE 3 Average health costs and years of life lost per patient and incremental cost-effectiveness ratio pre- versus post-implementation.

	RMP-led model	MRaCC/ROCC model	Pooled data
n (hospitalisations)[a]	4629	3333	7962
Years of life lost per hospitalisation	0.96	0.86	0.10
95%CI or *p*-value	(0.78–1.12)	(0.66–1.05)	$p = 0.4572$
Average incremental cost/hospitalisation	$1147	$1449	−$302
95%CI or *p*-value	($1145–$1149)	($1446 to $1452)	$p < 0.001$
ICER			−$3051
95%CI or *p*-value	(−$90 020 to $83918), $p = 0.9450$		

[a]Number of hospitalisations vary from the total shown in Table 1 due to mismatches occurring as a result of inability to perfectly link the different data sets required for this analysis (e.g. RFDS with inpatient admissions data).

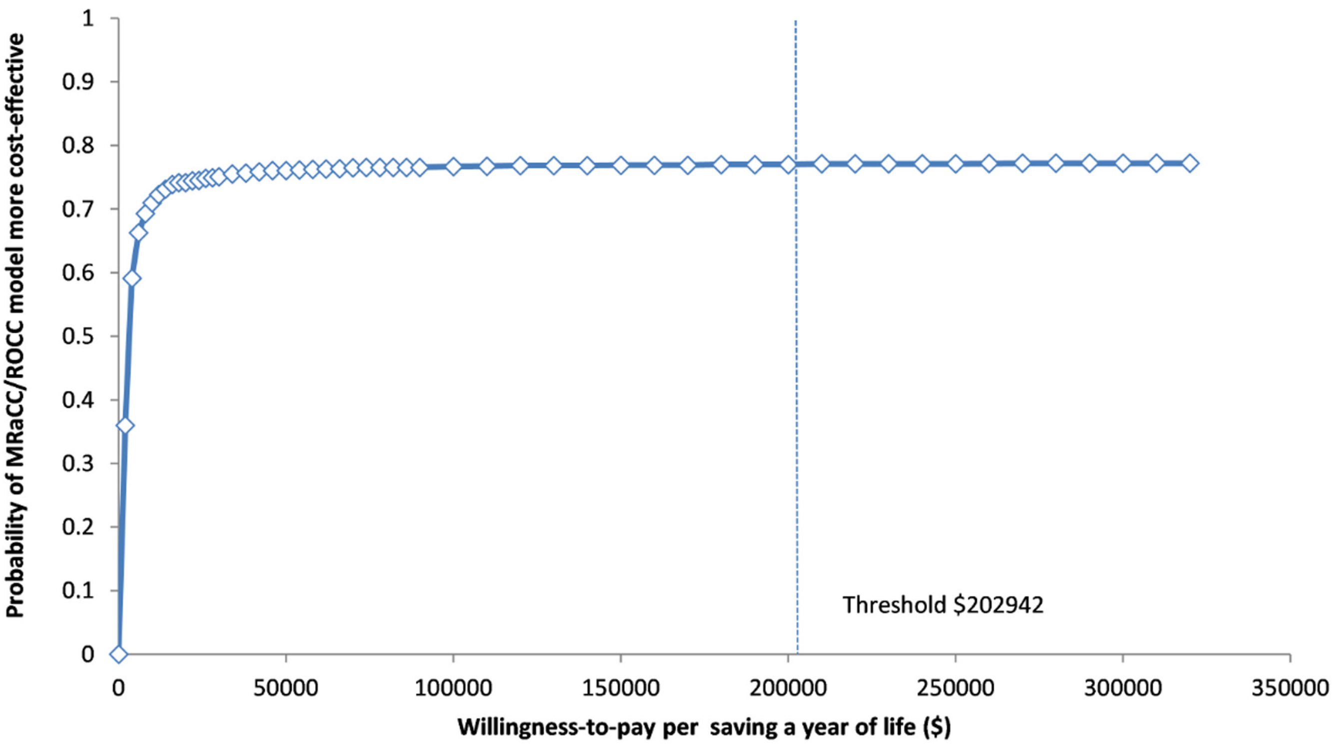

FIGURE 3 Acceptability curve for comparing cost-effectiveness (cost per year of life saved) of post-implementation model.

in terms of saving years of life compared to the previous RMP-led model.

4 | DISCUSSION

This evaluation is the first peer-reviewed cost-effectiveness study of a remote aeromedical retrieval model redesign.[6] Key findings include that the newly implemented MRaCC/ROCC model – which separates acute care from primary health care referral streams, and provides a 60% increase in rostered doctor hours together with an increase in the proportion of doctors with critical care skills – is associated with statistically significantly lower rates of retrievals, ED presentations and hospital admissions – all of which are approximately 10% lower than under the previous RMP-led model. We estimate that reduced hospitalisation rates associated with the new MRaCC/ROCC model could save NT DoH $744 528 per year. The social and out of pocket costs associated with patient evacuation, relocation of family members and repatriation could also be substantial. The evaluation found no statistically significant difference in the hazard of dying at any time within the first year of a consultation. However, at an increased cost of only $302 more per retrieved and hospitalised patient than the previous RMP-led model, it is about 75% probable that the new model is cost-effective in saving YLLs. The high probability of cost-effectiveness is of great policy importance, more so because of the high health needs and resource constrained context of Central Australia, suggesting that significant improvements in health outcomes can be achieved with comparatively small incremental investments in the health system.

Quantitative analyses reveal that aeromedical retrieval timeliness, when measured as the time from initial consultation until aircraft departure on an aeromedical retrieval mission, is on average 18 min faster post-implementation, which is statistically significant. While we did not detect any significant difference in time from initial consultation until ED arrival or hospital admission, qualitative data reported elsewhere indicated that remote clinicians using the aeromedical retrieval systems generally perceive that they are able to access more timely advice in emergencies under the new model and that the aeromedical retrieval activation process is faster.[19] Our findings, especially when triangulated with qualitative data,[19] strongly suggest that the model re-design is having its intended effect of reducing the time from initial referral until "wheels up" in emergencies. The assessment of timeliness of retrievals, however, is complex. Not all retrievals have the same degree of urgency and assessments of the degree of urgency may have varied systematically depending on RMP and MRaCC consultants' experience and levels of training. On occasions it is likely to be appropriate to delay retrievals for safety reasons, until daylight, for example, or while waiting for fresh crews to commence shifts. Less urgent retrievals may also be appropriately delayed because of competing demands on the limited available infrastructure. Additionally, given that flight times to retrieve patients located in remote and very remote communities to hospital are long, it is likely that other indicators of timeliness, such as time to definitive care (which may be provided by clinicians in remote communities with the patient, working under the instruction of clinicians in regional centres with advanced critical care skills) may be a more appropriate indicator of timeliness than the timeliness indicators available to use in this study.

Overall, these findings are of great importance for informing remote aeromedical retrieval policy development. This is particularly the case where existing retrieval models rely on doctors with GP qualifications (but with no requirement for advanced critical care skills) as initial respondents and where referral calls are not differentiated by acuity of patients' conditions. The findings of this study indicate that transitioning from a GP-led model to dual primary care and emergency streams, wherein the primary care stream is led by GPs whereas the emergency stream is led by doctors (Rural Generalists or specialist physicians) with advanced critical care skills, could be associated with better health system efficiencies while simultaneously being cost-effective in saving years of life.

This study uses a strong pre- and post-implementation observational study design. However, it is limited by the lack of other comparable controls. It did not use an experimental design since post-implementation randomisation is both impractical and unethical. This limitation means that it is difficult to attribute improvements in system efficiency entirely to the implementation of the MRaCC/ROCC model, as there were general health system changes that occurred at about the same time as the MRaCC/ROCC model was introduced. These include the introduction of a Remote Early Warning Score (REWS) which remote clinicians commenced using to assess patients' vital signs and oxygen saturation which then informs decisions about referral pathways and timelines. Over time, there has also been increased availability of point of care testing which has been shown to be independently associated with changing triage decisions, improving clinical decision making about the need for retrieval and reducing unnecessary retrievals.[20,21] Further, Australia's standardised death rates have been gradually declining over time and these changes are not taken into account.

Additionally, the analyses described in this study are limited to using administrative data, which has inherent limitations. While it was possible to specifically identify consultations by MRaCC consultants, it was more difficult to differentiate RMP telehealth consultations from face-to-face consultations by RMPs located in remote communities. Imperfect merging of RFDS retrieval records with hospitalisation and ED data using encrypted Hospital Record Numbers (HRNs) is a further limitation. HRNs were not available for 5.5% of patients retrieved by RFDS, and therefore these patients were not included in the analyses using hospitalisation and emergency department data. Despite limitations associated with analyses of administrative data, the broader study utilises mixed methods, which means that we are able to triangulate administrative data with data from a range of other sources, including quantitative and qualitative responses to two surveys and qualitative findings emerging from thematic analysis of in-depth semi-structured interview data, thereby considerably strengthening the overall study design.[19,22]

5 | CONCLUSIONS

This research considerably strengthens the scant extant remote retrieval systems literature which until now lacked the cost-effectiveness analyses so critical for informing health policy development and allocating scarce public dollars. The implementation of the

MRaCC/ROCC model in Central Australia in February 2018 is associated with significantly reduced retrieval and hospitalisation rates, cost savings associated with reduced hospitalisations and has a high probability of being cost-effective in saving years of life. These findings are highly relevant to other remote regions in Australia and internationally that have comparable GP-led retrieval services.

AUTHOR CONTRIBUTIONS

Deborah Jane Russell: Funding acquisition; data curation; formal analysis; writing – original draft; investigation; methodology; project administration; supervision; resources. **Yuejen Zhao:** Funding acquisition; data curation; formal analysis; writing – review and editing; investigation; visualization; methodology; resources. **Supriya Mathew:** Funding acquisition; writing – review and editing; investigation; project administration; resources. **Michelle Susannah Fitts:** Writing – review and editing; investigation; project administration; supervision. **Richard Johnson:** Conceptualization; funding acquisition; data curation; writing – review and editing; validation; investigation; methodology; resources. **David Mark Reeve:** Data curation; writing – review and editing; validation; investigation. **Bridget Honan:** Writing – review and editing; validation; investigation. **Petra Niclasen:** Data curation; writing – review and editing; validation; investigation. **Zania Liddle:** Writing – review and editing; investigation. **Danielle Green:** Writing – review and editing; investigation. **John Wakerman:** Conceptualization; funding acquisition; writing – review and editing; investigation; methodology; project administration; supervision; resources.

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CONFLICT OF INTEREST STATEMENT

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ETHICS STATEMENT

The research was approved by the Central Australian Human Research Ethics Committee (Ref: CA-19-3320).

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SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

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