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Original Research

Time to treatment and outcomes for aneurysmal subarachnoid haemorrhage in metropolitan versus remote areas: A Queensland population analysis

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ABSTRACT

Background: Aneurysmal subarachnoid haemorrhage (aSAH) is a life-threatening condition that demands prompt neurosurgical intervention. In Australia, the vast geographic distances and the substantial proportion of the population living in rural or remote areas may hinder access to timely care, potentially influencing patient outcomes. Although medical retrieval services are well-established and regional centres provide primary care, patients with aSAH in remote areas may experience poorer outcomes compared to those in urban centres. This study aims to assess clinical outcomes between patients from remote regions and major cities in a prospective cohort analysis.

Methods: Patients presenting with aSAH to the Royal Brisbane and Women's Hospital within 3 days post-ictus were prospectively enrolled to an aneurysmal subarachnoid haemorrhage database. Demographic, clinical, management, and outcome data were collected. Primary outcomes including the modified Rankin Scale (mRS), mortality, and the need for permanent cerebrospinal fluid (CSF) diversion, were assessed at 1-year post-ictus.

Results: A total of 114 patients met the inclusion criteria, with 57 patients (50 %) retrieved from regional or remote centres (ASGS 2–5). Average retrieval distance was 349.1 km (230.6–467.5 km). No significant differences were observed in 1-year mRS (1.8, 1.2–2.3 vs 1.2, 0.8–1.6, $p = 0.09$), mortality (10.5 % vs 3.5 %, 0.14), or the need for permanent CSF diversion (26.3 %, 17.9 %, $p = 0.28$) between the patients in major cities or rural centres respectively. Furthermore, time to ventriculostomy was not significantly different.

Conclusion: Patients with aSAH from regional and remote areas of Queensland do not experience worse clinical outcomes compared to those from major cities. The presence of robust medical retrieval services and primary care infrastructure, combined with the centralisation of neurosurgical expertise, likely contributes to comparable outcomes despite geographic challenges.

1. Introduction

Aneurysmal subarachnoid haemorrhage (aSAH) is a critical and life-threatening condition that requires immediate medical intervention. It occurs following the spontaneous rupture of an intracranial aneurysm, leading to haemorrhage into the subarachnoid space and often resulting in stroke, coma, or death [1]. Population studies estimate that 3–4 % of individuals harbor intracranial aneurysms, with an annualised rupture risk of 2–4 % [2,3]. Approximately one-third of patients do not survive the insult, while half of all survivors are left with disability [4].

During the acute phase of aSAH, mortality is driven by several factors, including mass effect from the haemorrhage, obstructive hydrocephalus due to intraventricular bleeding, seizures, and stroke. As a result, urgent treatment at a tertiary neurosurgical facility is considered

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the gold standard and has shown to be associated with better outcomes [5]. This care typically includes blood pressure control, airway management, treatment of hydrocephalus, and definitive interventions to secure the aneurysm [6].

Australia's population distribution presents unique challenges in providing rapid access to neurosurgical care, particularly in rural and remote areas [7]. With 27 million people spread across 7.7 million square kilometres—equating to just 3 people per square kilometre—access to specialised healthcare services can be difficult, especially in vast regions like Queensland. Queensland alone spans 1.9 million square kilometres with a population of 5.1 million, requiring careful planning and resource management to meet the healthcare needs of residents in regional and remote areas [3,8].

Skilled medical retrieval services have been established to improve access to care, but neurosurgical services remain concentrated in major urban centres [8]. Conditions like aSAH, which demand rapid and highly specialised care, pose a significant challenge in terms of timely access across large geographic distances. Decentralising neurosurgical services to regional centres may help reduce these barriers, providing more timely interventions and improving patient outcomes in rural areas [7]. Studies in stroke care, for example, have demonstrated benefits of decentralisation, with regional stroke units linked to better access to timely treatment and improved outcomes [9]. Decentralised services can also address healthcare equity by reducing geographic disparities in service provision [10].

However, centralised high-volume centres for neurosurgery and endovascular treatment are often associated with superior outcomes for rare and complex conditions such as aSAH [11–13]. Centralised care allows for the concentration of expertise, advanced technology, and multidisciplinary teams, which can result in better clinical outcomes [12,13].Economies of scale in specialised care further support centralisation, with some evidence that high-volume centres are more cost-effective and deliver more consistent quality of care [14]. Studies in the United States have demonstrated improved outcomes in aneurysmal subarachnoid haemorrhage for patients treated in high-volume centralised centres [15].

Prior study has demonstrated significant difference in outcomes following aSAH in Australia based on socioeconomic status [16]. However, the impact of geographic isolation on outcomes following aneurysmal subarachnoid haemorrhage (aSAH) in Australia remains unclear within the context of current statewide medical infrastructure [7]. Given Australia's vast landmass and dispersed population, this issue is not only relevant locally but also in other regions worldwide facing similar healthcare challenges. We conducted a prospective cohort analysis to assess how geographical isolation affects clinical outcomes in aSAH patients. Our findings are directly applicable to other areas with large regional and remote populations, offering important insights into managing specialised care across geographic barriers.

2. Methods

Ethical approval for this study was granted by the Institutional Review Committee. A RedCap© database was developed for the prospective patient enrolment and collection of demographic, pathological, intervention, and outcome data.

Patients presenting to the Royal Brisbane and Women's Hospital (RBWH) in Queensland within three days of ictus were eligible for inclusion. Informed consent was obtained from the patient or their next of kin within 24 h of presentation. Exclusion criteria included non-aneurysmal cause of subarachnoid haemorrhage, age less than 18-years old, or predicted death within 24-hours due to a catastrophic haemorrhage. The severity of aSAH was assessed using validated scales, including the World Federation of Neurological Surgery (WFNS) grading system and the modified Fisher score (mFS). Clinical data were collected by review of electronic medical records, including radiology and pathology databases for a 14-day period following the ictus.

Collected patient variables included gender, age, ethnicity, comorbidities, lifestyle habits (such as smoking and alcohol use), and current medications. Presenting clinical features included WFNS grade, mFS, pupil reactivity on arrival at RBWH, aneurysm size and location, and baseline biochemical markers. Data on definitive management techniques, timing, and the requirement for ventriculostomy were also recorded. Primary outcomes were mortality, modified Rankin Score (mRS) at 1-year post-ictus, and time to ventriculostomy. The need for ventriculoperitoneal shunt (VPS) or permanent cerebrospinal fluid (CSF) diversion was a secondary outcome of assessment.

Geographical location was determined based on the patient's residence at the time of ictus, as described by the patient or their next of kin. The Australian Statistical Geography Standard System (ASGS) was used to categorize locations into metropolitan or regional/remote areas. For analysis, patients were grouped into major cities (ASGS 1) or regional/remote (ASGS 2–5).

Statistical Analysis Data were analysed using STATA Statistical Software for Data Science ©. The Shapiro-Wilk test was used to assess normality. For normally distributed data, means and standard deviations (mean ± SD) were reported, while medians with 95 % confidence intervals were used for non-normally distributed data. Associations were tested using Student's paired *t*-test for normal distributions and Mann-Whitney *U* test for non-normal distributions. Categorical variables were analysed using the Chi-squared test.

3. Results

A total of 114 patients met the inclusion criteria for the final analysis. The average patient age was 56.8 years (54.55–59.03), with an equal gender distribution (57 males and 57 females). A family history of aneurysm was noted in 12 patients (10.5 %), and more than half (60 patients, 52.6 %) had no significant medical comorbidities. A smoking history, either current or past, was recorded in 56 patients (49.1 %). There was no significant difference in risk factors including smoking and alcohol consumption (Table 1).

Patients were equally distributed between major cities (57, 50 %) and remote regions (57, 50 %). The average distance to the nearest neurosurgical facility was significantly greater for patients in remote

Table 1
Patient demographics and baseline characteristics by geographic location.

	Major cities (n = 57)	Regional and remote (n = 57)	P value
Demographics			
Gender			
Male	21 (36.8)	15 (26.3)	
Female	15 (26.3)	42 (73.7)	*0.23*
Age	58.0 (54.7–61.3)	55.6 (52.5–58.7)	*0.27*
ATSI	1 (1.8)	5 (8.8)	*0.09*
Medical History			
BMI	27.2 (25.5–28.9)	28.0 (26.4–29.5)	*0.34*
HTN	22 (38.6)	18 (31.6)	*0.43*
Hyperlipidaemia	11 (19.3)	14 (24.6)	*0.50*
T2DM	6 (10.5)	3 (5.3)	*0.30*
No medical history	29 (50.1)	31 (54.4)	*0.71*
Family history	5 (8.9)	7 (12.5)	*0.54*
Lifestyle			
Smoker			
Current	19 (34.6)	20 (36.4)	
Previous	6 (10.9)	11 (20)	
Never	30 (54.6)	24 (43.6)	*0.34*
Excessive EtOH	13 (22.8)	6 (10.5)	*0.08*
Medications			
Antiplatelet	4 (7.1)	6 (10.7)	*0.51*
Anticoagulant	3 (5.4)	1 (1.8)	*0.31*

regions (349.1 km, 230.6–467.5 km) compared to those in metropolitan areas (54.7 km, 33.5–75.9 km, $p < 0.001$). The time from initial CT imaging to arrival at a neurosurgical centre was also significantly longer for remote patients (6.5 h, 5.5–7.5 h) compared to their metropolitan counterparts (4.2 h, 3.4–5.0 h, $p < 0.0001$). Although remote patients obtained their initial CT scan more quickly (1.6 h, 1.0–2.2 h) than those in major cities (3.9 h, 1.2–9.0 h), this difference was not statistically significant ($p = 0.59$).

There was a minor put statistically significant difference in WFNS grades between patients from major cities (2.3, 1.9–2.6) and remote areas (1.8, 1.4–2.1, $p = 0.03$). One-third of all patients (38, 33.3 %) were intubated upon arrival at the Royal Brisbane and Women's Hospital. The majority of aneurysms were located in the anterior circulation (93, 81.5 %), with an average size of 5.9 mm (5.36–6.44 mm). Acute hydrocephalus requiring ventriculostomy was more common in patients from major cities (39, 68.4 %) than in those from remote regions (28, 49.1 %, $p = 0.04$). However, there was no significant difference in the average time to ventriculostomy between patients from major cities (23.5 h, 17.2–29.9 h) and those from remote areas (17.6 h, 13.8–21.4 h, $p = 0.63$).

Patients from major cities had lower presenting plasma sodium levels (136.9 mmol/L, 136.1–137.7 mmol/L) compared to those from remote areas (138.0 mmol/L, 137.3–138.8 mmol/L, $p = 0.05$). No significant differences were observed in the presenting modified Fisher score (mFS), aneurysm characteristics, or baseline biochemical analyses between the two groups (Table 2).

Treatment modality was evenly split, with 47 patients (50 %) undergoing surgical management and 57 patients (50 %) receiving endovascular treatment. The average time to definitive treatment was not significantly different between metropolitan patients (33.4 h, 28.2–38.6 h) and remote patients (41.0 h, 30.9–51.4 h, $p = 0.4$). At the 1-year follow-up, the average modified Rankin Score (mRS) was 1.46 (1.13–1.78), indicating outcomes within the range of minimal to slight disability. There was no significant difference in mRS between patients from major cities (1.8, 1.2–2.3) and those from remote regions (1.2, 0.8–1.6, $p = 0.09$). Chronic hydrocephalus requiring permanent cerebrospinal fluid diversion was present in 25 patients (21.9 %), and 8 patients (7.0 %) died as a result of aSAH during their in-hospital treatment episode.

4. Discussion

To our knowledge, this is the first analysis of geographical disparity in aneurysmal subarachnoid haemorrhage (aSAH) outcomes within Australia. The prospective design allows for bias control and standardisation of outcomes such as mRS. Given the country's expansive landmass and widely distributed population, some residents live thousands of kilometres from tertiary care, potentially compromising their access to critical neurosurgical services. This challenge must be balanced against the necessity for centralising specialised neurosurgical services to improve patient outcomes. Although modern medical infrastructure has introduced skilled retrieval services to mitigate disparities in access, evidence on patient outcomes in this context remains limited. Our study finds that patients residing in remote areas do not experience worse clinical outcomes compared to those in major cities (Table 3). Specifically, there were no significant differences in mortality rates, modified Rankin Score (mRS) at one year, or the need for permanent cerebrospinal fluid (CSF) diversion.

The time from the onset of symptoms to initial presentation at a medical facility and subsequent CT imaging was not significantly different between remote and metropolitan patients (Fig. 2). This reflects adequate access to non-tertiary care centres, including medical imaging, in rural and remote areas [17,18]. However, the time taken to reach a neurosurgical facility was significantly longer for regional and remote patients (Fig. 2), which is consistent with the greater transfer distances (Fig. 1). Despite this, because CT imaging was readily available and the time from ictus to presentation was shorter in regional/remote areas, there was no overall delay in reaching a neurosurgical centre (Fig. 2). Effective retrieval services, including fixed-wing aircraft, helicopters, and ambulances, have allowed for high-level care in remote areas, as shown by the 2.3-hour difference in transfer time from CT imaging to a neurosurgical facility [18].

Although the time from ictus to presentation and the time to CT imaging did not differ significantly, a trend toward delayed presentation and investigation in metropolitan areas offset any transfer time advantage, which might have otherwise delayed treatment for regional/remote patients. Cultural factors in major cities, such as delayed symptom recognition or overcrowded emergency departments, may have contributed to the slower diagnosis and investigation times for metropolitan patients. However, this contrasts with previous studies, which suggest that high patient volume and access to CT scanners do not contribute to delays in diagnosing aSAH [19].

Prompt CT imaging is a cornerstone of patient management [20]. However, a subset of patients presenting with delayed symptoms and negative CT findings may require lumbar puncture for xanthochromia testing. In rural or regional settings, CSF xanthochromia testing for this subgroup can lead to diagnostic delays, potentially worsening outcomes. However, usual practice in Queensland would dictate treating as an aSAH presenting with a suspicious history and an aneurysm present on CTA. Diagnosis based on LP results is rare with modern CT scanning

Table 2
Initial clinical presentation and aneurysm characteristics by geographic location.

	Major cities (n = 57)	Regional and remote (n = 57)	P value
Presentation			
WFNS	2.3 (1.9–2.6)	1.8 (1.4–2.1)	*0.03*
mFS	3.2 (2.9–3.4)	2.9 (2.6–3.2)	*0.22*
Unreactive pupil	3 (5.3)	2 (3.5)	*0.65*
Intubated	20 (35.1)	18 (31.6)	*0.69*
Aneurysm			
Anterior circ	49 (86.0)	44 (77.2)	
Posterior circ	8 (14.0)	13 (22.8)	*0.23*
Left hemisphere	18 (50)	13 (48.2)	*0.88*
Aneurysm size	6.3 (5.5–7.2)	5.5 (4.8–6.1)	*0.20*
Laboratory			
Hb	139.5 (135.5–143.4)	136.9 (133.0–140.8)	*0.36*
Na	136.9 (136.1–137.7)	138.0 (137.3–138.8)	*0.05*
WCC	15.6 (10.9–20.2)	12.0 (10.9–13.0)	*0.18*
Plt	280.1 (260.7–299.4)	277.5 (244.9–310.1)	*0.21*

Table 3
Treatment and outcomes of aSAH by geographic location.

	Major cities (n = 57)	Regional and remote (n = 57)	P value
Treatment			
EVD	39 (68.4)	28 (49.1)	***0.04***
Ictus to EVD	23.5 (17.2–29.9)	17.6 (13.8–21.4)	*0.63*
Ictus to treatment	33.4 (28.2–38.6)	41 (30.9–51.4)	*0.4*
Treatment modality			
Surgical	19 (33.3)	38 (66.7)	
Endovascular	13 (22.8)	44 (77.2)	*0.21*
Outcomes			
VP Shunt	15 (26.3)	10 (17.9)	*0.28*
Modified Rankin score	1.8 (1.2–2.3)	1.2 (0.8–1.6)	*0.09*
Mortality	6 (10.5)	2 (3.5)	*0.14*

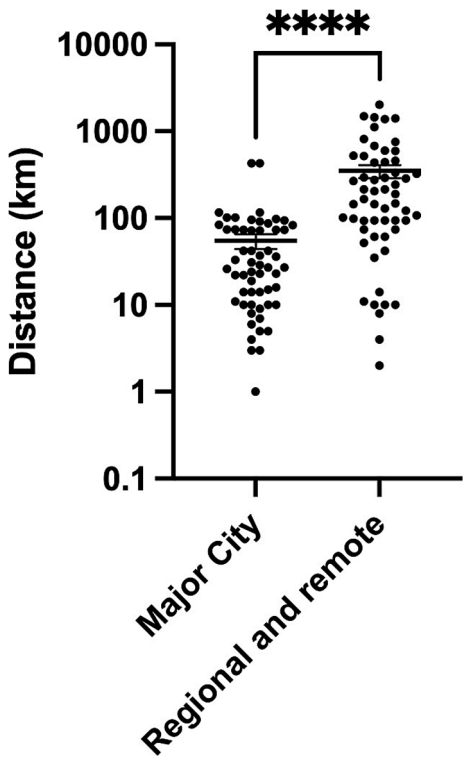

Fig. 1. Geographic Distance to Neurosurgical Center for aSAH Patients. This figure shows the distribution of distances (in kilometers, logarithmic scale) between patients' location at time of ictus and a neurosurgical center. Patients are categorized as living in major cities (ASGS 1) or regional/remote areas (ASGS 2–5). Student's T-test p-value ($p < 0.0001$).

techniques, our study recruited patients within 72 h of ictus and no patients were recruited based on positive xanthochromia in the absence of acute haemorrhage on CT.

In the rural/regional setting, in addition to the lack of neurosurgical services, local specialist intensive care services, including invasive arterial blood pressure monitoring, may be limited. Support of patients presenting to aSAH is often completed in the local emergency department resuscitation bay prior to transfer. Patient outcomes are supported by timely imaging, telehealth consultations with neurosurgical centres, centralised retrieval coordination run by consultant intensivists and rapid specialised retrieval services.

Prior studies have suggested outcomes for patients transferred to a neurosurgical facility are worse than patients that present directly [21,22]. We did not observe this difference. This is consistent with a prior study finding ultra-early (<24 h) aneurysm securing following aSAH does not improve patient outcomes [23]. Patients from major cities were more likely to present with worse WFNS grades and were more likely to require ventriculostomy (Table 2, Table 3). Importantly, the time to ventriculostomy in patients with acute hydrocephalus did not differ significantly between groups (Table 2), reinforcing the effectiveness of retrieval services and supporting transfer over local neurosurgical intervention in remote areas [8]. Our cohort of low-grade subarachnoid haemorrhage patients does not demonstrate a difference in functional or mortality outcome despite this, however this analysis cannot be generalised to high grade aSAH patients.

A limitation of the study includes non-enrolment of patients not admitted under a neurosurgical unit. This may include patients with haemorrhage deemed to be non-survivable on admission to the emergency department. It is therefore difficult to comment on whether there may be underlying differences on the threshold for intervention between patients presenting to metropolitan and rural/regional areas. It seems likely, given the higher WFNS grade in the metropolitan cohort, that patients with high grade haemorrhages that may be palliated regionally

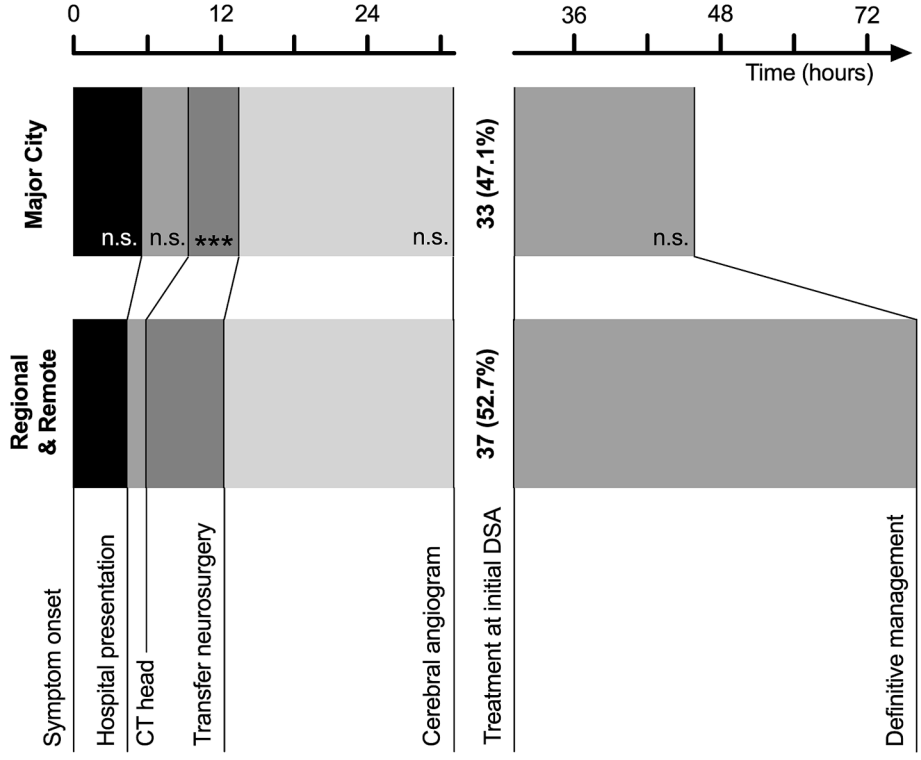

Fig. 2. Timeline of aSAH Care: From Symptom Onset to Definitive Treatment. This figure illustrates the time elapsed from the onset of aSAH symptoms to various stages of carefor patients from major cities and regional/remote areas. Steps of care are indicated by grey shaded areas and differences between groups are denoted by annotations (n.s. = not significant, $p > 0.05$; *** = $p < 0.001$). Definitive treatment refers to either endovascular or surgical intervention to address the ruptured aneurysm.

are admitted under a neurosurgical unit when presenting to a neurosurgical centre. This is also reflected in the higher mortality rates for patients from metropolitan regions (6 vs. 2, Table 3). Unfortunately, access to the denominator data from feeder hospitals within the catchment area is not available retrospectively.

We also note the difficulty of controlling for genetic variation that may be present in isolated remote communities. Genome-wide association studies (GWAS) have identified several genetic loci associated with aneurysm formation, including CDKN2A/B, SOX17, and the 9p21 chromosomal region [24]. These genetic alterations affect vessel wall integrity, inflammation, and homeostasis. For instance, Bilguvar and Yasuno [25] demonstrated an association between the CDKN2A/B genetic locus and aneurysm formation. They found the frequency of this genetic variation was markedly increased in Japanese populations compared to European populations, despite a similar effect size on aneurysm risk. While assessing genome-level changes in the populations studied is beyond the scope of this study, it is important to note that metropolitan areas tend to have more multicultural communities, whereas remote and regional areas often have a higher proportion of Indigenous inhabitants. There is no available data on the genetic variations in these populations and how they may affect outcomes from aSAH.

The prospective, single-centre, nature of this study has ensured uniform, high-quality data collection and clear comparisons between groups. The Royal Brisbane and Women's Hospital in Brisbane, Queensland's largest city, serves a vast geographical catchment area. The greatest transfer distance in this study was more than 2000 km. However, we have also noted challenges in recruiting patients with high-grade aSAHs due to distressed families, and the pre-transfer palliation of patients in peripheral centres. Local factors governing medical decision-making in feeder hospitals could not be controlled, potentially influencing outcomes. This experience provides valuable insight on the challenges to overcome for future prospective studies on aSAH.

Despite these limitations, we present a study that provides a real-world, meaningful comparison of geographically diverse patient populations applicable to other international areas facing similar barriers to care. This study demonstrates that equitable outcomes in aSAH can be achieved with a centralised referral process. However, whist the results presented here demonstrate the equality of outcomes in Queensland, other state and national retrieval systems may differ.

5. Conclusion

In conclusion, patients from rural and remote areas of Queensland do not experience worse clinical outcomes following aSAH compared to those living in major cities. Modern medical infrastructure in Australia, including specialised retrieval services, networked primary care facilities in remote regions, and the centralisation of neurosurgical services, supports equitable clinical outcomes for patients with this life-threatening condition, regardless of geographical location. In the future, larger multicentre studies may allow for cohort matched analysis to confirm these results whilst controlling for variations between metropolitan and remote/regional populations.

CRediT authorship contribution statement

Charles F. Yates: Writing – review & editing, Writing – original draft, Methodology, Formal analysis, Data curation. **Annabelle Harbison:** Writing – review & editing. **Michael Stuart:** Writing – review & editing, Methodology. **Dayna Roeland:** Writing – review & editing, Writing – original draft, Data curation. **Liam G. Coulthard:** Writing – review & editing, Methodology, Formal analysis, Conceptualization.

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Declaration of competing 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.

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