Heliyon 9 (2023) e16993

Contents lists available at ScienceDirect

Heliyon

journal homepage: www.cell.com/heliyon

Splenic trauma in the Northern Territory; the impact of an interventional radiology service on splenic trauma management and outcomes

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ARTICLE INFO

Keywords:
Spleen
Trauma
Rural
Interventional radiology
Splenic angioembolization
Australia

ABSTRACT

Background: The spleen is the most commonly injured organ in abdominal trauma. Guidelines suggest non-operative management (NOM) is preferred over splenectomy for all haemodynamically stable patients, regardless of injury severity. The availability of splenic angioembolization has been shown to improve outcomes for high-grade splenic injuries by decreasing failure rates of NOM. Trauma incidence and fatality rates are higher in regional and remote areas, and rurality is associated with increased mortality from trauma. Additionally, rural hospitals have difficulty with staff retention and may offer less specialist services compared with urban centres.
Methods: A single-centre retrospective cohort study was conducted at the Royal Darwin Hospital, using the National Critical Care and Trauma Response Centre database. All patients with splenic injury admitted between January 2018 and December 2021 were selected, and divided into control and intervention cohorts, before and after January 1, 2020, correlating with interventional radiology availability. Demographic information included age, gender, mechanism of injury, AIS grade of splenic injury, injury severity score, and shock index. The primary outcome was management of splenic injury and failure rate of NOM. Secondary outcomes included mortality, ICU length of stay and hospital length of stay.
Results: Sixty-six patients met inclusion criteria, 32 controls and 34 interventions. Intervention and control groups were statistically similar for baseline demographics, and outcome measures of mortality and ICU length of stay. There was significant difference in the management of splenic injury, either OM or NOM, between intervention and control cohorts among high-grade splenic injury patients (AIS grade 4 and 5). In logistic regression analysis, the absence of interventional radiology was associated with increased OM (OR 12.8, SE 15.7, $p = 0.04$, 95%CI 1.15–142).
Conclusion: The absence of an interventional radiology service was associated with an increased risk of operative management, suggesting interventional radiology helps to prevent splenectomy, improving long term outcomes for splenic trauma patients in regional settings. The effects of availability of IR seen in international publications on decreased mortality and shorter length of stay were not replicated in this study.

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https://doi.org/10.1016/j.heliyon.2023.e16993
Received 17 December 2022; Received in revised form 4 May 2023; Accepted 2 June 2023
Available online 3 June 2023

1. Introduction

The spleen is the most commonly injured organ in blunt abdominal trauma, accounting for up to a third of traumatic abdominal organ injuries [1]. The accepted classification of splenic injury severity is the modified American Association for Surgery of Trauma (AAST) classification, using CT findings to classify injuries into grades I–V [2]. Grade of injury is correlated with increasing risk of mortality [3], and is used to guide management decisions regarding operative (OM) or non-operative management (NOM). The most recent World Society for Emergency Surgery guidelines recommend laparotomy as gold standard management for any haemodynamically unstable patient, and NOM for all haemodynamically stable patients, regardless of injury severity and concomitant injuries [4,5]. Non-operative management, including splenic angioembolization (SAE), is preferred over splenectomy to preserve splenic function, which decreases life-long risks of septic complications and overwhelming post splenectomy infection [6,7]. The non-operative approach also avoids other potential fatal complications of operative management, including complications associated with laparotomy [8], and has also been associated with shorter hospital stay, shorter ICU stay, lower blood transfusion requirements, lower mortality compared with operative management [9,10], and is low cost [11].

The recent trend towards NOM is heavily influenced by the availability of (SAE) as an adjunct to NOM. SAE has been shown to improve outcomes for high-grade splenic injuries by decreasing failure rates of NOM [12,13,14,15]. Current evidence suggests there is little to no role for SAE in Grade I and II injuries, but good evidence to support use the of SAE in Grade IV and V injuries [4,14,16]. However, the use of SAE for Grade III injuries remains controversial [8,12,13,17,18,19,20,21]. Notably, while associated with improved clinical outcomes by reducing NOM failure, SAE is not without complications, such as splenic abscess, contrast induced renal insufficiency, and access site haematoma, though these are less common and less significant than operative complications [22,23]. For patients who present haemodynamically unstable but respond to initial resuscitation, SAE and OM have a similar effect on mortality [24].

Failure of non-operative management (fNOM) is associated with poor outcomes such as increased mortality, complications, and length of stay [25,26]. The incidence of fNOM is approximately 10% [13], and there is consensus in the literature that SAE reduces the risk of fNOM in high-grade splenic injuries [17,27]. Australian studies from Level-1 Trauma Centres have documented failure rates between 3.5 and 18% [17,28], noting that definitions of fNOM have varied across studies, with some considering SAE a failure rather than an adjunct to NOM. The decision of when to perform splenectomy varies across centres, and this along with the difference of definitions may account for some of the degree of variation.

There are many complexities of trauma care in Australia, including rurality. Globally, injury incidence and trauma fatality rates are higher in regional and remote areas [29]. Assessments of the impact of rurality in Australia and New Zealand have revealed trauma patients from rural areas to be younger than urban patients, and rurality to be associated with increased mortality and rate of trauma hospitalisation [30,31]. Rural and remote hospitals also have difficulty with staff retention, and may offer less specialist services than their urban tertiary trauma centre counterparts [32]. Within the Northern Territory health system, there was a period where Royal Darwin Hospital was unable to provide an interventional radiology service, due to complex relationships between the Northern Territory Department of Health and multiple interventional radiology contractors, despite having the infrastructure available. The following study will aim to assess the presentations, management, and outcomes of splenic trauma patients in a regional setting, with a focus on the impact of a regularly staffed interventional radiology service on management and outcomes.

2. Methods

2.1. Study design

The following is a single-centre retrospective cohort study conducted at the Royal Darwin Hospital (RDH) in the Northern Territory, Australia. The National Critical Care and Trauma Response Centre (NCCTRC) operates from the RDH site and collects an extensive trauma database which was utilised for this study. This research was approved by the Human Research Ethics Committee of the Northern Territory at the Menzies School of Health Research (NT HREC Reference Number: 2022–4437).

2.2. Setting and participants

The RDH is a 360-bed tertiary hospital in the Northern Territory with a territory-wide Level 2 Trauma centre that is the major trauma care provider for the NT. The hospital manages over 800 trauma admissions per annum and employs specialists in trauma surgery, vascular surgery, neurosurgery, orthopaedic surgery, and other subspecialties.

For this study, all patients with a splenic injury admitted to the RDH trauma service between January 2018 and December 2021 were identified, and the data pertaining to their admission sourced from the NCCTRC database. Patients were only admitted to the trauma service if they presented to the emergency department as a 'trauma call' or 'trauma alert' and met criteria, had injury severity scores (ISS) ≥ 9, or required Intensive Care (ICU) admission. The NCCTRC database was able to supply epidemiological data, as well as Abbreviated Injury Scale (AIS) Code relating to splenic injury.

The availability of interventional radiology staff, who perform angio-embolization of the splenic vessels, has varied at RDH over the 48 months of data collection. Between the years 2018–2019 there was no regular IR service, with a full-time IR specialists being employed from January 2020 through to December 2021 and available both in and out of hours. As such, the periods of 2018–2019 and 2020–2021 were identified as control, or interventional radiology unavailable (IRU), and intervention, or interventional radiology available (IRA) cohorts respectively. Exclusion criteria included those cases of penetrating splenic or abdominal injury, and those cases who underwent operative management related to another abdominal organ injury not requiring splenic intervention.

The grade of splenic injury was classified according to AIS severity. AIS grade two injuries correlate with AAST Grade I and II injuries, whereas AIS grade three, four and five injuries are synonymous with AAST Grades III, IV and V injuries respectively [16].

The final decision to proceed with non-operative, operative, or angiographic intervention was guided by the general surgeon on call. Medical records were reviewed of cases who underwent operative management or splenic angioembolization to determine the intended initial management, whether that be operative or non-operative, and the success rates associated with those plans. Medical records were also reviewed to determine the cause of death and concurrent injuries in the case of mortality, as well as splenic function of patients following angioembolization, determined by absence of Howell-Jolly bodies on blood film at follow up.

2.3. Variables

Patients meeting the inclusion criteria were divided into either IRU or IRA cohorts, depending on whether their date of admission was before or after January 1, 2020. Demographic information extracted included age, gender, mechanism of injury, AIS grade of splenic injury, ISS, heart rate in beats-per-minute, and systolic blood pressure in mmHg as first recorded in the emergency department. Shock Index (SI) was used as a measure of haemodynamic stability, calculated as heart rate ÷ systolic blood pressure. Binary risk variables were created for age >40 [33], high risk SI defined as SI $\geq$ 0.9 [8, 34] and high risk ISS defined as ISS $\geq$25 [4, 33, 35]. The primary outcome was management of splenic injury and failure rate of NOM. Failure was defined as requiring surgical intervention after initial documented intention of non-operative management, or as non-operative management resulting in death. Secondary outcomes included mortality, ICU admission, ICU length of stay and hospital length of stay. Operative and embolized cases were assessed for appropriate management including vaccinations and antibiotics on discharge.

2.4. Statistical analyses

Central tendency of continuous variables was assessed graphically. Continuous quantitative variables were summarized by median and interquartile range, or mean and standard deviation. Categorical variables were summarized as proportions. Univariate statistics

Table 1
Baseline characteristics and outcomes.

	Total	2018/19 (IRU)	2020/21 (IRA)	p value
Exposure	n = 66	n = 32	n = 34	
Age	31.9 [14.5]	29.2 [15.8]	34.4 [13.0]	0.14 (t = −1.48)
Age>40	18 (27.3%)	6 (18.8%)	12 (35.3%)	0.13
Gender				0.87
Male	46 (69.7%)	22 (68.8%)	24 (70.6%)	
Female	20 (30.3%)	10 (31.2%)	10 (29.4%)	
Mechanism of injury				0.12 ‡
Traffic accident	27 (40.9%)	17 (53.1%)	10 (29.4%)	
Assault	16 (24.2%)	4 (12.5%)	12 (35.3%)	
Fall	12 (18.2%)	6 (18.8%)	6 (17.65%)	
Other	11 (16.7%)	5 (15.6%)	6 (17.65%)	
ISS †	18 [12–25]	20 [12–29]	17 [12–25]	0.23 (z = 1.20)
Grade of splenic injury (AIS score)				0.24 ‡
2	20 (30.3%)	11 (34.4%)	9 (26.5%)	
3	20 (30.3%)	12 (37.5%)	8 (23.5%)	
4	17 (25.8%)	7 (21.9%)	10 (29.4%)	
5	9 (13.6%)	2 (6.2%)	7 (20.6%)	
High grade	26 (39.4%)	9 (28%)	17 (50%)	
Shock Index	0.83 [0.28] (n = 61)	0.87 [0.29] (n = 23)	0.79 [0.28] (n = 33)	0.28 (t = 1.08)
High Risk SI	23 (34.9%)	12 (37.5%)	11 (32.4%)	0.66
SBP †	115 [103–130] (n = 61)	115 [103–128] (n = 28)	118 [103–130] (n = 33)	0.66 (z = −0.44)
HR	96 [24.1] (n = 64)	99 [23.4] (n = 30)	93 [24.1] (n = 34)	0.35 (t = 0.93)
Outcome				
Management				0.11 ‡
NOM	58 (87.9%)	26 (81.3%)	32 (94.1%)	
Subgroup – SAE	11 (16.7%)	0	11 (32.3%)	
OM	8 (12.1%)	6 (18.7%)	2 (5.9%)	
fNOM	3/61 (4.9%)	3/29 (10.3%)	0/32 (0.0%)	0.10 ‡
Mortality	2/66 (3.0%)	2/32 (6.3%)	0 (0.0%)	0.23 ‡
ICU LOS †	2.76 [1.57–4.65]	2.75 [1.49–4.60]	2.81 [1.57–5.05]	0.88 (z = −0.15)
Hospital LOS †	5.96 [3.67–10.37]	6.59 [3.70–13.5]	5.35 [3.67–9.55]	0.52 (z = 0.65)

fNOM – proportion of cases intended for NOM who required OM.
Continuous measures reported as mean [sd], compared with two-tailed *t*-test unless otherwise noted. Proportions compared with Pearson's χ^2 unless otherwise noted.
† Median [IQR] reported, Mann Whitney *U* test for comparison of means.
‡ Fisher's exact test.

such as Pearson's χ^2 test and Fisher's exact test, and bivariate statistics such as Mann Whitney *U* test and two-tailed Student's *t*-test were used to determine the similarity of exposure and outcome measures of the two cohorts. These tests were also used to identify differences in exposure and outcome measures stratified by grade of splenic injury. A secondary analysis using binomial logistic regression was conducted on the subset of patients with high grade splenic injury, classified as AIS four or five, to determine the impact of interventional radiology availability on management and outcome measures. Multivariate analysis was conducted to assess the effect potential confounding variables ISS >25, age >40, and shock index >0.9. All analyses were performed using Stata/BE version 17.0 (StataCorp, College Station, TX, USA).

3. Results

A total of 71 patients were admitted to RDH with splenic injury over the four-year study period. Five patients were excluded from the analysis based on the exclusion criteria above. Of the remaining 66 patients, 32 presented in 2018–2019 and were labelled the IRU arm, whereas 34 presented in 2020–2021, which was labelled the IRA arm.

Patients included in the study were 70% male. The mean age of the combined cohorts was 32 ± 14.5 years. The most common mechanism of injury was traffic accident at 41%, including car, motorbike, or other motor vehicle related trauma. This was followed by assault, accounting for 24% of cases, most commonly by domestic partner. Falls from height and other mechanisms of injury, such as animal related trauma and recreational sporting activities, accounted for the remainder of presentations. The median ISS was 18, with an IQR of 12–25. Low-grade splenic injuries, defined as AIS two and three were more common than high-grade injuries, defined as AIS four and five.

3.1. Patient characteristics and outcomes in IR unavailable and IR available groups

Baseline characteristics of the two cohorts were similar, with age, gender, mechanism of injury, SI, ISS, and AIS grade of splenic injury almost symmetrical between the cohorts, as shown in [Table 1]. There were seven patients with grade 5 splenic injury in the IRA cohort, but only two in the IRU cohort. When categorised as high-grade and low-grade splenic injury, there were more high-grade injuries in the IRA cohort, 50% compared with 28%. Non-operative management, including patients who underwent SAE as an adjunct, accounted for 88% of all cases. Eleven patients, representing 17% of the whole, underwent angioembolization. Eight of eleven patients received proximal embolization, and three distal. Six patients proceeded directly to interventional radiology, with a mean time from presentation to procedure of 5hrs 50 min. There was no significant difference in management, ICU length of stay, or hospital length of stay between the two cohorts [Table 1]. Notably, there were no failures of non-operative management or mortalities in the IRA cohort. The two mortalities in this cohort had low-grade splenic injuries, with cause of death related to non-survivable intracranial

Table 2
Exposure and outcomes stratified by low-grade or high-grade splenic injury.

Exposure	Low-grade (n = 40)		p value	High-grade (n = 26)		p value
	IRU (n=23)	IRA (n=17)		IRU (n=9)	IRA (n=17)	
Age	28.4 [17.0]	32.4 [13.2]	0.43 (t = −0.80)	31.1 [13.0]	36.5 [12.8]	0.32 (t = −1.01)
Age>40[b]	4 (17.4%)	5 (29.4%)	0.46	2 (22.2%)	7 (41.2%)	0.42
Gender[b]			1.00			1.00
Male	16 (69.6%)	12 (70.6%)		6 (66.7%)	12 (70.6%)	
Female	7 (30.4%)	5 (29.4%)		3 (33.3%)	5 (29.4%)	
Mechanism of injury[b]			0.17			0.55
Traffic accident	13 (56.5%)	6 (35.3%)		4 (44.4%)	4 (23.5%)	
Assault	1 (4.4%)	5 (29.4%)		3 (33.3%)	7 (41.2%)	
Fall	6 (26.1%)	3 (17.7%)		0	3 (17.7%)	
Other	3 (13.0%)	3 (17.6%)		2 (22.2%)	3 (17.7%)	
ISS[a]	20 [10–29]	12 [9–18]	0.04*	21 [18–25]	20 [17–26]	0.89
Shock Index	0.82 [0.26] (n = 19)	0.72 [0.28]	0.27 (t = 1.11)	0.84 [0.35]	0.83 [0.28]	0.89 (t = 0.14)
High Risk SI[b]	9 (39.1%)	5 (29.4%)	0.74	3 (33.3%)	6 (35.3%)	1.00
SBP[a]	115 [105–126] (n = 19)	108 [103–130]	0.99	115 [99–130]	125 [97–138]	0.59
HR	100 [23.0] (n = 21)	87 [25.2]	0.11 (t = 1.66)	91 [23.6]	98 [24.0]	0.49 (t = −0.70)
Outcome						
Management			1.00			0.03*
NOM	21 (91.3%)	16 (94.1%)		5 (55.6%)	16 (94.1%)	
SAE[c]	0	2 (11.8%)		0	9 (52.9%)	
OM	2 (8.7%)	1 (5.9%)		4 (44.4%)	1 (5.9%)	
fNOM[b]	1/22 (4.5%)	0	1.00	2/7 (28.6%)	0	0.08
Mortality[b]	2/23 (8.7%)	0	0.50	0	0	
ICU LOS[a]	1.4 [0–3.3]	1.3 [0–4.2]	0.96	2.7 [1.8–4.9]	2.2 [1.2–3.4]	0.59
Hospital LOS[a]	4.8 [2.9–16.4]	4.9 [2.5–8.3]	0.71	7.7 [6.6–9.0]	6.0 [4.1–9.6]	0.29

*$p < 0.05$.
[a] Median [IQR] reported, Mann Whitney *U* test for comparison of means.
[b] Fisher's exact test.
[c] SAE – splenic angioembolization. Noted here as a subgroup of NOM.

and cardiac injuries rather than splenic injuries.

3.2. Patient characteristics and outcomes, by grade of splenic injury

Patients undergoing SAE as an adjunct to NOM had predominantly high-grade splenic injury. Two cases had grade three injury, six cases had grade four injury, and three cases had grade five injury. As illustrated by these results, and suggested in the literature, interventional radiology has the most impact on management of high-grade splenic injuries [18]. A stratified analysis by low-grade and high-grade splenic injury is shown in [Table 2].

IRA and IRU groups were similar for baseline and outcome variables among low-grade splenic injury, except for ISS which was higher in the IRU group (median 20 and 12 respectively, $p = 0.04$). Among high-grade splenic injuries, management was significantly different between IRA and IRU cohorts, with regard to the choice of OM or NOM. In the IRU group, four of nine cases required OM, 44%, while in the IRA group, only one of seventeen required OM ($p = 0.03$). In the IRA cohort, of those with high-grade injury for which angiography is recommended [4], uptake of SAE was 9 of 17 patients, 52.9%.

3.3. Absence of IR as a risk factor for OM

A subgroup analysis of the high-grade splenic injury cohort with binomial logistic regression was performed to assess the absence of interventional radiology as a risk factor for requiring operative management. The odds ratio (OR) for operative management in the absence of interventional radiology was 12.8 ($p = 0.04$, 95%CI 1.15–142). Other documented risk factors for failure of NOM and need for operative intervention, ISS >25, age >40, and shock index >0.9 were studied in univariate analysis [Table 3]. As none of these factors were associated with operative management, they were not considered confounding variables, and thus multivariate logistic regression analysis was not required.

All patients who underwent operative management or splenic angioembolization were given splenic vaccinations prior to discharge. All OM patients were prescribed antibiotics on discharge, but only seven of eleven SAE cases received antibiotics. Antibiotic prescription was not associated with location of angioembolization, proximal or distal. All patients who had angioembolization retained splenic function on follow up, regardless of proximal or distal embolization, and there were no significant reported complications following OM or SAE.

4. Discussion

The study aimed to examine the presentations, management, and outcomes of splenic trauma patients in a regional setting, with a focus on the impact of a regularly staffed interventional radiology service on management and outcomes. Among those with high-grade splenic injury, the absence of interventional radiology was a risk factor for operative management, that is, a risk factor for splenectomy. Four of nine patients required operative intervention when IR was unavailable, and only one of seventeen patients required operative intervention when IR was available. This is reflected in international literature from rural centres without IR, where splenectomy rates are higher in rural centres than urban centres [9,36]. Prevention of splenectomy where possible is critical for long term immune function and prevention of overwhelming post-splenectomy infection [6,8]. It is known that SAE is associated with both short and long-term preservation of splenic function [7,37], highlighting the importance of an IR service for splenic trauma patients.

In addition to staffing challenges faced generally by rural centres, IR is currently a rapidly emerging subspecialty of the Royal Australian and New Zealand College of Radiologists, which is not yet formally recognised in Australia and New Zealand, despite IR having international recognition [38]. To adequately staff a regional centre, usually upwards of three specialists are required to facilitate a 24hr service with safe working hours at our centre. Formal recognition of this subspecialty is expected to increase staff availability in the future, including in regional centres.

It should be noted that this study was significantly underpowered to calculate an odds ratio of 12.8 in this population. Assuming the incidence of operative management is around 10%, a sample size of 122 patients per group would be required to give an estimate with 50% precision. Additionally, the study is underpowered to comment on the small subset of fNOM in this population, meaning the failure rate lower than 10% as reported in the literature [13] may be due to small sample size. Despite this, the raw data suggest a clinical difference in management within this small population at a single centre.

The proportion of patients presenting with high-grade compared with low-grade splenic injury in this study, 39% compared with 61%, is consistent with data from other Australian Trauma Centres [17]. This study may overestimate the severity of injury in the general NT population, as patients with low-grade isolated splenic injury are likely to be excluded from this study based on low ISS or

Table 3
Binomial logistic regression – risk factors for operative management among high grade splenic injury patients.

Risk Factor	OR	SE	p value	95% CI
Absence of IR	12.8	15.7	0.04*	1.15–142
ISS >25	2.00	2.03	0.49	0.27–14.6
Age >40	1.33	1.36	0.78	0.18–9.91
Shock Index >0.9	0.41	0.49	0.46	0.04–4.31

*$p < 0.05$.

not requiring hospital admission.

There is a wealth of literature to suggest that angioembolization is a useful adjunct for non-operative management of splenic injury, associated with shorter length of ICU stays, shorter hospital stays and fewer complications [4,5,10,12,13]. Previous analyses have compared patients by intervention received, however no previous studies have assessed the impact of the introduction of an interventional radiology service, where it was not previously available. Given the well reported benefits of SAE [12,13,25,26], there was an expectation that the presence of an interventional radiology service may be associated with improved clinical outcomes compared with the cohort for whom interventional radiology was not an option. Although mean length of hospital stay was one day longer in the IRU cohort, there was no statistically significant difference in mortality, ICU length of stay, or hospital length of stay. Additionally, there were no significant complications following intervention. The increased risk of splenectomy in the absence of IR highlights an important consideration for other rural trauma centres without an IR service. For patients who are haemodynamically stable with vascular injury or active contrast extravasation on CT [4], we suggest careful consideration and discussion about the suitability of transfer to another centre for embolization, as an alternative to splenectomy.

Splenic angiography is recommended for haemodynamically stable patients with grade 4 or 5 injury, and in this study, when IR was available, only 52.9% of patients had angioembolization, representing a possible underutilization of this resource. The reason for this is not clear, and may be related to patient factors, staffing, or surgeon discretion. Two patients who underwent angioembolization in this cohort had grade three splenic injury, a controversial decision in current literature [8,12,13,17,18,19,20,21]. Of note, among grade three injuries, there were no failures of non-operative management, suggesting SAE may have contributed for these two grade three patients.

Secondary outcome measures of vaccination and antibiotics were reviewed, with all SAE and OM patients receiving vaccinations, and inconsistent prescription of prophylactic antibiotics among SAE patients. The most recent practice management guidelines from the Eastern Association for the Surgery of Trauma conditionally recommend against vaccination post angioembolization [39], and in systematic review, SAE patients did not require prophylactic antibiotics [40].

5. Conclusion

The effect of the availability of IR seen in international publications has not been fully replicated in this study at a single rural trauma centre, with regards to mortality, hospital length of stay and ICU stays. However, this study demonstrated the absence of an interventional radiology service was associated with an increased risk of operative management. This highlights the importance of appropriate rural staffing, in particular providing an interventional radiology service in rural trauma hospitals to help prevent splenectomy, and improve long term outcomes for splenic trauma patients in regional settings.

Author contribution statement

Ashleigh Spittle:

1) conceived and designed the experiments,
2) performed the experiments
3) analysed and interpreted the data, wrote the paper.
4) contributed reagents, materials, analysis tools or data
5) wrote the paper

Alex Britcliffe:

2) performed the experiments
3) analyzed and interpreted the data
5) wrote the paper

Mark Hamilton:

1) conceived and designed the experiments
2) contributed reagents, materials, analysis tools or data
5) wrote the paper

Data availability statement

Data will be made available on request.

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.

Acknowledgements

With thanks to my supervisor, Mr Mark Hamilton, the staff at the National Critical Care and Trauma Response Centre, in particular Huat Lim, Belinda Nolan, and Jenny Santhosh, the staff at the Royal Darwin Hospital Department of Surgery, and my family.

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