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Original Article

Volume–outcome relationships for tracheostomies in Australia and New Zealand Intensive Care Units: A registry-based retrospective study

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ABSTRACT

Objective: It is unknown whether a volume–outcome relationship exists for patients who receive tracheostomy in the intensive care unit (ICU) as has been observed in other healthcare settings. This study aimed to determine the average number of tracheostomies performed per intensivist per ICU in Australia and New Zealand and associations with case fatality.

Design: A retrospective cohort study of adult ICU admissions was conducted.

Setting: Data from the Australia and New Zealand Intensive Care Society Adult Patient Database and Critical care resources registry were linked and analysed over the time period extending from 01 January 2018 to 31 March 2023.

Participants: The study population included adults (aged ≥18 years) admitted to Australia and New Zealand ICUs who received tracheostomy.

Intervention: No intervention was reported.

Main outcome measures: The primary exposure variable was tracheostomies per intensivist (TPIs), which was calculated as (the number of patients who had tracheostomy inserted during their ICU admission)/(the total number of intensivists), for each site for each financial year.

Results: There were 9318 patients from 172 ICUs over a 5-year period, from January 2018 to March 2023, who received tracheostomies and were included in this analysis. The median TPI value was 3.1 (interquartile range: 1.9–4.3). Raw case fatality in the total cohort was 13.7% (1280/9318). The lowest adjusted risk of death (8.5%, 95% confidence interval: 3.63%–13.36%) was observed when the TPI value was equal to 10.3, with higher risk of death observed at lower values of TPI.

Conclusions: A volume–outcome relationship was observed between TPI value and hospital case fatality, with lower case fatality at higher TPI values across the entire range of TPI.

1. Introduction

The last several decades have seen advances in the evaluation of healthcare outcomes that focussed on determinants of survival in patients undergoing medical and surgical procedures.[1–5] Volume–outcome relationships, whereby outcomes improve with increased volume of practice at an institutional or individual practitioner level, especially in surgical disciplines, have been

Abbreviations: TPI, tracheostomy per intensivist; CICM, College of Intensive Care Medicine; FTE, full-time equivalent; ICU, intensive care unit; IQR, interquartile range; CI, confidence interval; APD, Adult Patient Database; CRRT, continuous renal replacement therapy.

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described. Several primary studies indicate that higher operating volumes are associated with better patient outcomes.[6–10] Few studies directly examined the volume–outcome relationship in the intensive care unit (ICU), mostly from an organisational perspective as a quality improvement initiative to assess processes of care.[11–13]

Tracheostomy is a commonly performed procedure offering many advantages over prolonged endotracheal intubation such as the following: reducing oropharyngeal and laryngeal trauma, reducing work of breathing, improving pulmonary secretion clearance, and reducing the use of sedation, duration of mechanical ventilation, and consequently length of ICU and hospital stay.[14,15] Tracheostomy by the open surgical tracheostomy method is usually performed by general Surgeons or otorhinolaryngology surgeons and percutaneous dilatational tracheostomy, by intensivists.[15,16] There has been extensive research published on tracheostomy indications, timing including meta-analyses, and reviews on various aspects of management of tracheostomies in the ICU.[17–22]

A study done in the United States of America (USA) observed that the proportion of ICU patients receiving tracheostomy increased rapidly through 2008, after which the proportion declined from 9.8% to 8.7%.[23] Similar findings have been reported by the National Confidential Enquiry into Patient Outcome and Death in 2014, that subsequent to TracMan trial,[24] the proportion of tracheostomies performed in ventilated patients fell recording a relative reduction of 34% (from 19.8% to 13.1%) over the 4-year study period.[25] An epidemiological retrospective study done in Australia has also reported halving of the number of tracheostomies performed with associated reduction in adjusted mortality by half (from 26.5% to 16.5%) from 2004 to 2014.[26] Currently, it is unknown whether volume–outcome relationships exist for the care of patients with tracheostomies in the ICU. To address this gap, we devised this study to evaluate volume–outcome relationships for patients requiring tracheostomies in Australia and New Zealand (ANZ) ICUs.

The primary objective of this study was to evaluate associations between volume of tracheostomies (i.e., the number of patients requiring tracheostomy during their ICU admission) and patient outcomes including hospital case fatality, ICU and hospital lengths of stay, and mechanical ventilation hours. We have also evaluated the heterogeneity of volume–outcome relationships for tracheostomies across different types of ICUs, patient demographics, and diagnostic groups.

2. Materials and methods

2.1. Study design

We performed a binational, retrospective, observational study using clinical and administrative data collected from the Adult Patient Database (APD) and Critical Care Resources Registry (CCR), two high-quality databases administered by the Australia and New Zealand Intensive Care Society Centre for Outcome Research Evaluation, over the time period extending from 01 January 2018 to 31 March 2023.

2.2. Data sources and study population

The APD collects patient episodes from over 90% of ICUs across ANZ, primarily used to benchmark the performance of individual contributing units including information about demographic, medical, vital status, frailty score, severity of illness score, and admission diagnoses.[27] The CCR data collect site-level data such as the number of beds, admissions, ICU readmissions, and workforce data such as full-time equivalent (FTE) of medical, nursing, and allied health staff.[28] A staff member working at one FTE will work on average, for 80 h per fortnight.

Site-level data from the CCR were linked to patient-data by site and financial year such that all patients admitted at a site during a financial year had the same site-level variables assigned to them. The APD and CCR classify ICUs as metropolitan, rural/remote, tertiary, or private ICUs. ICUs in ANZ are mostly staffed by specialist intensive care physicians who hold fellowship qualifications from the College of Intensive Care Medicine (CICM) of ANZ.[29] However, some ICUs may be staffed by specialist physicians who do not hold a CICM fellowship and may hold fellowship qualifications in anaesthesia, emergency medicine, or internal medicine. The CCR provides FTE data on both CICM fellowship–qualified physicians (CICM-FTE) and physicians with alternate specialist qualifications (non-CICM-FTE). The total intensivist FTE was calculated as CICM-FTE plus non-CICM-FTE.

The study population included adults (aged $\geq$18 years) admitted to ANZ ICUs who received tracheostomy with corresponding site-level data available on the CCR. The study exclusion criteria included data unavailability for key variables—variable of interest including tracheostomy, hospital outcomes, and CCR data on intensivist FTE. This study was approved by the Royal Brisbane and Women's Hospital Human Research Ethics Committee (HREC/2023/MNHA/97425) with an individual consent waiver and was reported according to the guidelines provided in the Strengthening the Reporting of Observational studies in Epidemiology statement.[30]

2.3. Statistical analysis

Continuous data were assessed for normality and summarised as mean and standard deviation (if normally distributed) or median and interquartile range (IQR) (if not normally distributed). Categorical data were summarised as proportions. Missing data for various variables have been identified and documented as relevant. Univariable comparisons were performed using the Pearson chi-squared and Wilcoxon sank-sum tests for categorical and continuous data, respectively.

The primary exposure variable was tracheostomies per intensivist (TPI), which was calculated as (the number of patients who had tracheostomy inserted during their ICU admission)/(the total number of intensivists), for each site for each financial year. The numerator only included patients who received a tracheostomy during their ICU admission. This meant that patients who had pre-existing tracheostomies or were admitted to the ICU after a surgical procedure that required tracheostomy insertion (for example, total laryngectomy) were not included. The APD does not collect data on who performed the tracheostomy; thus, we could not differentiate between percutaneous dilatational tracheostomy performed in the ICU versus surgical tracheostomy performed in the operating theatre. As such, the TPI variable incorporated overall management of the patients with tracheostomies, rather than the insertion procedure alone. The volume–outcome relationships in the ICU, in general, are incompletely characterised, and hence we propose TPI as a novel variable that encompasses not just the actual procedure of tracheostomy insertion but also patient selection, post-procedural care, and ongoing management (sedation, ventilation, weaning, cuff deflation, mobilisation, and so forth) of patients with tracheostomies.

A TPI was assigned to each patient based on their site and financial year (determined by date of ICU admission as date of tracheostomy insertion is not available in the APD).

Temporal trends in the TPI value were evaluated by visual inspection of tracheostomies and TPI over time, with the use of parametric and nonparametric tests planned if visual trends existed.

The primary outcome was hospital case fatality with secondary outcomes of nonhome discharge, hospital length of stay, and ICU length of stay. Volume–outcome relationships between TPI and patient outcomes were assessed using mixed-effect regression models (logistic regression for hospital case fatality and nonhome discharge and log-transformed linear regression for hospital and ICU length of stay). Site was used as a random effect, with patients nested within sites. The following fixed effects, all known to be strongly associated with outcomes from critical illness, were included in the models: age, sex, ANZROD (ANZ risk of death) score and elective status (elective versus nonelective admission). The annual number of admissions was also added as a fixed effect to include the effect of overall ICU volume in the model.

Nonhome discharge was defined as live discharge to a location other than the patient's usual residence. This included nursing home, other chronic care facility, palliative care, rehabilitation, mental health facility, or other hospital. Given that death is a competing for nonhome discharge, a Fine–Grey competing risk analysis was also performed, with results reported as sub-distribution hazard ratios with 95% confidence interval.

The possibility of nonlinear associations between TPIs and patient outcomes were explored by visualisation of the relationship using locally weighted scatterplot smoothing (LOWESS). Restricted cubic splines with four knots were used to allow for nonlinear associations between TPI and patient outcomes.

We examined a range of prespecified subgroups that included patients admitted to the ICU with a respiratory illness, sepsis diagnoses, trauma, neurotrauma, and frail patients. Frailty was assessed using the Clinical Frailty Scale (CFS), with CFS 1–4

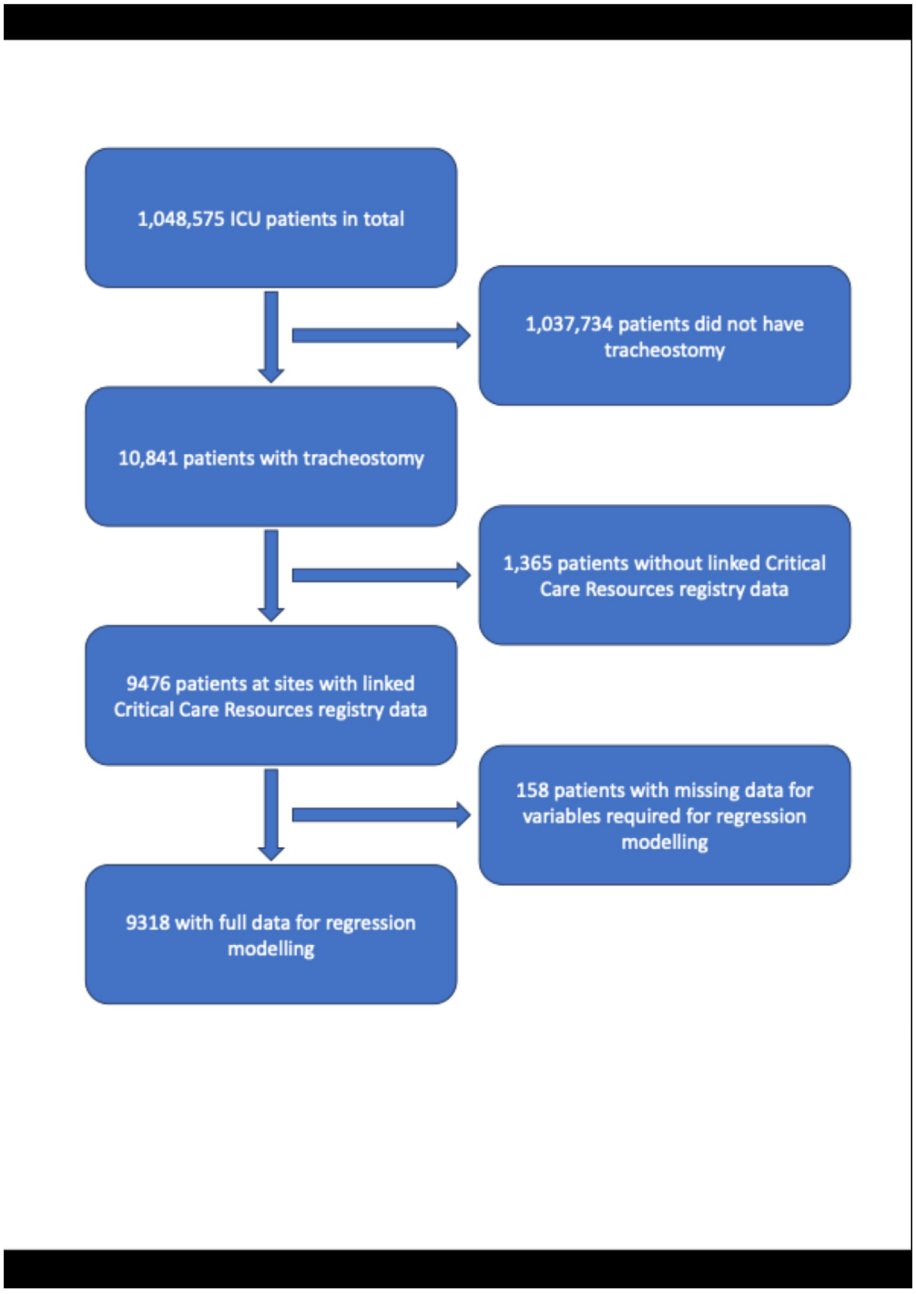

Fig. 1. Patient flow chart. ICU: intensive care unit.

regarded as nonfrail and CFS 5–8 regarded as frail.[28] The missing data have been reported as relevant.

Statistical analysis was performed using a proprietary statistical package STATA (version 17.0, StataCorp, TX-USA).

3. Results

3.1. Patient characteristics and associations

During the study period, 10841 patients admitted to 172 ANZ ICUs received a tracheostomy during their ICU admission (Fig. 1). Of these, we were able to link 9476 (87.4%) APD records to the CCR. After exclusions, 9318 (98.3%) patients with linkage and no missing data for primary exposure and outcome variables were included in this study. Of these patients, 8038 (86.3%) patients survived, of which 5372 (66.8%) were male. The median age of ICU patients receiving tracheostomy who survived during study period was 58.5 years (IQR: 44.7–68.7). Of the cohort of survivors, 6377 (79.3%) tracheostomy recipients were admitted to tertiary ICUs, 746 (9.3%) to metropolitan ICUs, 465 (5.8%) to rural/remote ICUs, and 450 (5.6%) to private ICUs. There were 195 of 9318 (2.1%) patients who had pre-existing chronic renal failure requiring dialysis. These patients had a significantly higher fatality rate than those without chronic renal failure (49/195, 25.1 % vs 1231/9122, 13.5%, $p < 0.001$). Patients with pre-existing cardiovascular, liver, and immunological diseases had higher fatality rates than those who did not have these diseases (Table 1). In nonsurvivors, the most common diagnostic criteria was respiratory disease (126 [9.8%]), and they had higher scores of frailty (CFS: 7–8: 6.8% versus 3.7%, $p < 0.001$). Diabetes in tracheostomy recipients accounted for higher mortality, with 30.9% being nonsurvivors ($p < 0.001$). Median Acute Physiology and Chronic Health Evaluation II score (22 [IQR: 17–28], $p < 0.001$) and ANZ risk of death (0.2 [IQR: 0.08–0.44], $p < 0.001$) were also significantly higher in tracheostomised nonsurvivors. The nonsurvivors also received longer duration of mechanical ventilation (464 h [IQR: 237–756.5] versus 315 h [IQR: 33–569], $p < 0.001$) and continuous renal replacement therapy (533 patients [41.6%] versus 1398 patients [17.4%], $p < 0.001$). The tracheostomised nonsurvivors had a longer ICU length of stay (580 h [IQR: 344.5–918.3], $p < 0.001$) and shorter hospital length of stay (841.5 h [IQR: 510.7–1388.2] $p < 0.001$) than the tracheostomised survivors (435.8 [IQR: 143.3–751]) and (957.3 [IQR: 530.8–1568.7]), respectively (Table 1) and patient characterisitics by TPI quartiles was shown in supplementary Table S1.

3.2. Tracheostomies and sites

The majority of patients with tracheostomies during the study period were admitted to tertiary ICUs 78.7% (7331/9318), followed by metropolitan 9.9% (929/9318), rural 5.7% (533/9318), and private 5.6% (525/9318) hospitals. The median total intensive care specialist FTE during the study period was 8.9 (IQR: 6.3–11.4) across the 172 sites, with tertiary ICUs having a maximum median of 10 FTEs (IQR: 8.4–12.8; $p < 0.001$). Breakdown by CICM and non-CICM

Table 1
Patient characteristics.

Variable		Alive	Died	Total	P value
		N = 8038 (%)	N = 1280 (%)	N = 9318 (%)	
Age n		58.54 (44.71–68.71)	65.3 (54.37–72.94)	59.58 (45.93–69.56)	<0.001
Sex n (%)	Male	5372 (66.8%)	857 (67.0%)	6229 (66.8%)	0.93
	Female	2666 (33.2%)	423 (33.0%)	3089 (33.2%)	
Hospital	Metropolitan	746 (9.3%)	183 (14.3%)	929 (10.0%)	<0.001
Classification n (%)	Private	450 (5.6%)	75 (5.9%)	525 (5.6%)	
	Rural/regional	465 (5.8%)	68 (5.3%)	533 (5.7%)	
	Tertiary	6377 (79.3%)	954 (74.5%)	7331 (78.7%)	
APACHE II comorbidities	Respiratory disease				0.003
	Yes	577 (7.2%)	126 (9.8%)	703 (7.5%)	
	No	7460 (92.8%)	1154 (90.2%)	8614 (92.4%)	
	Cardiovascular disease.				<0.001
	Yes	377 (4.7%)	105 (8.2%)	482 (5.2%)	
	No	7660 (95.3%)	1175 (91.8%)	8835 (94.8%)	
	Liver disease	1 (0.0%)	0 (0.0%)	1 (0.0%)	<0.001
	Yes	111 (1.4%)	36 (2.8%)	147 (1.6%)	
	No	7926 (98.6%)	1244 (97.2%)	9170 (98.4%)	
	Renal disease	1 (0.0%)	0 (0.0%)	1 (0.0%)	<0.001
	Yes	146 (1.8%)	49 (3.8%)	195 (2.1%)	
	No	7891 (98.2%)	1231 (96.2%)	9122 (97.9%)	
	Immune disorders	1 (0.0%)	0 (0.0%)	1 (0.0%)	<0.001
	Yes	234 (2.9%)	93 (7.3%)	327 (3.5%)	
	No	7803 (97.1%)	1187 (92.7%)	8990 (96.5%)	
Frailty score n (%)	CFS: 1–2	1762 (32.9%)	156 (17.8%)	1918 (30.8%)	<0.001
	CFS: 3–4	2726 (51.0%)	475 (54.3%)	3201 (51.4%)	
	CFS: 5–6	665 (12.4%)	184 (21.1%)	849 (13.6%)	
	CFS: 7–8	197 (3.7%)	59 (6.8%)	256 (4.1%)	
Diabetes n (%)	Yes	1237 (20.1%)	307 (30.9%)	1544 (21.6%)	<0.001
	No	4930 (79.9%)	686 (69.1%)	5616 (78.4%)	
ANZ risk of death		0.07 (0.02–0.2)	0.2 (0.08–0.44)	0.08 (0.02–0.23)	<0.001
APACHE II score		18 (13–23)	22 (17–28)	18 (14–24)	<0.001
Ventilation (hours)		315 (33–569)	464 (237–756.5)	334 (46–595)	<0.001
CRRT n (%)	Yes	1398 (17.4%)	533 (41.6%)	1931 (20.7%)	
	No	5804 (72.2%)	620 (48.4%)	6424 (68.9%)	
Hospital LOS (hours)		957.3 (530.8–1568.7)	841.5 (510.7–1388.2)	938.7 (527.7–1543.4)	<0.001
ICU LOS (hours)		435.8 (143.3–751)	580 (344.5–918.3)	457.8 (174.7–772.6)	<0.001

Data are presented as median (IQR) for continuous measures, and n (%) for categorical measures, APACHE II: Acute Physiology and Chronic Health Evaluation II, ANZ: Australia and New Zealand, CFS: Clinical Frailty Scale; CRRT: continuous renal replacement therapy, ICU: intensive care Unit, IQR: interquartile range, LOS: length of stay.

Table 2
Tracheostomy per intensivist versus site characteristics.

	Metropolitan	Tertiary	Private	Rural/remote	Total	P value
	N = 929	N = 7331	N = 525	N = 533	N = 9318	
Total tracheostomies	10 (6–19)	52 (36–71)	5 (3–8)	7 (4–13)	44 (23–66)	<0.001
Total intensivists	8 (6–9)	14 (11–18)	7 (6–8)	6 (4–8)	14 (9–17)	<0.001
Total CICM specialists FTE	5.5 (4.5–6.5)	10 (8.4–12.8)	3.25 (2–4.5)	3.5 (2.5–4.5)	8.9 (6.3–11.4)	<0.001
Total nonCICM specialists FTE	0 (0–0.1)	0 (0–0)	0 (0–0)	0 (0–0.75)	0 (0–0)	<0.001
Total FTE	5.6 (4.8–6.5)	10 (8.4–12.8)	3.25 (2–4.5)	4 (3–5.9)	9.15 (6.5–11.4)	<0.001
RN critical care registration FTE	30.6 (15.96–43.6)	77.7 (23.4–104.4)	18.5 (10.9–25)	19.7 (15.1–24)	53 (15.2–93.4)	<0.001
Speech pathology FTE	0.1 (0–0.2)	0.3 (0–0.6)	0 (0–0.1)	0.1 (0–0.2)	0.2 (0–0.5)	<0.001
Total TPI (per intensivist)	1.3 (0.75–2.4)	3.5 (2.7–4.6)	0.8 (0.5–1.3)	1.5 (0.8–2)	3.1 (1.9–4.3)	<0.001
TPI (per intensivist FTE)	2.1 (1.2–3.1)	4.8 (3.4–6.4)	1.7 (1–4)	1.9 (1.2–2.5)	4.3 (2.8–6.1)	<0.001

Data are presented as median (IQR). CICM: College of Intensive Care Medicine, IQR: interquartile range, FTE: full-time equivalent, RN: registered nurse, TPI: tracheostomy per intensivist.

intensivists and other staffing data is provided in Table 2. The median total TPI was highest for tertiary ICUs (3.5 [IQR: 2.7–4.6]) followed by metropolitan ICUs (1.3 [IQR: 0.8–2.4]), rural/remote ICUs (1.5 [IQR: 0.8–2]) and private ICUs (0.8 [IQR: 0.5–1.3]) ($p < 0.001$) (Table 2). The median TPI over the study period (2018–2023) was stable (Fig. 2). The temporal trends for tracheostomies for the study period display minimal variation, as shown in Supplementary Table S4. Given the absence of linear relationship between year and TPI, significance testing was not performed.

3.3. Primary outcome: Hospital case fatality

On inspection of the LOWESS curve (Supplementary Figure S1), the univariable association between TPI and risk of death was found to be nonlinear ("u shaped"). Regression analyses were thus performed using restricted cubic splines with four knots to allow for nonlinear associations. After adjustment for age, sex, ANZROD score, hospital type, the annual number of admissions and elective admission in a mixed-effect logistic regression model with site as random effect, and patients nested within sites, the risk of death decreased as the TPI value increased across the range of TPI (Fig. 3). The lowest adjusted risk of death (8.5%, 95% confidence interval [CI]: 3.63%–13.36%) was observed when the TPI value was equal to 10.3, with a higher risk of death observed at lower values of TPI (Supplementary Table S2, Fig. 3).

3.4. Secondary outcomes

The secondary outcomes examined, ICU length of stay, hospital length of stay, and nonhome discharge, all had nonlinear associations with TPI (Supplementary Figures S2-4). The shortest length of ICU stay of 23.61 days (95% CI: 18.57–28.65 days) was observed at a TPI value of 10.3. The hospital length of stay was lowest (50.15 days [95% CI: 41.17–59.12]) at a TPI value of 6.33. The lowest nonhome discharge rate of 63.28% (95% CI: 54.76%–71.81%) occurred at a TPI value of 0.04 (Supplementary Table S2 and Figures S2-4).

3.5. Subgroup analyses

The association between the TPI value and risk of death within the prespecified subgroups varied between linear and nonlinear (Supplementary Table S2 and Figures S5–14). The association was

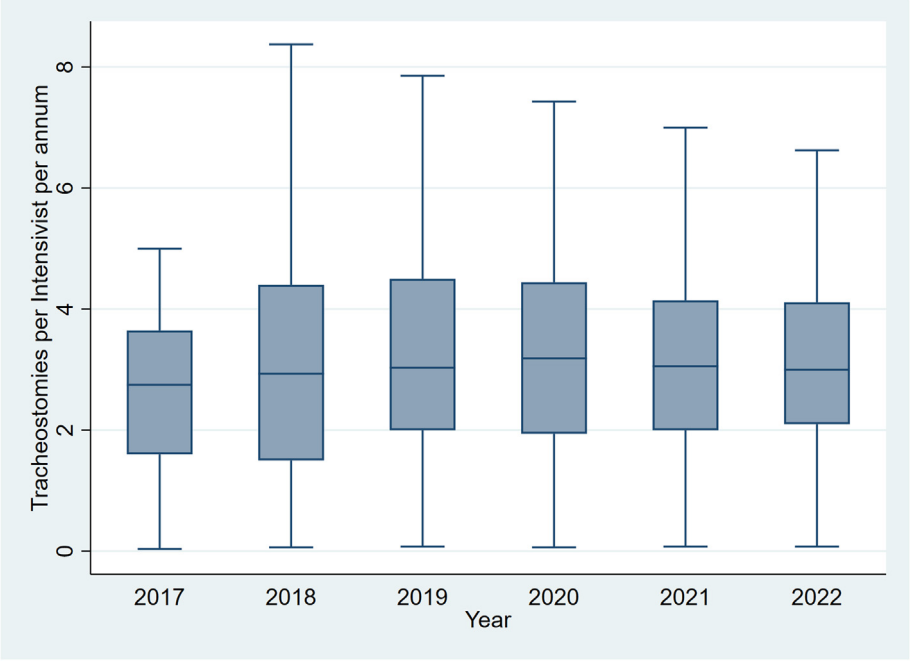

Fig. 2. Distribution of TPI by year. TPI: tracheostomy per intensivist.

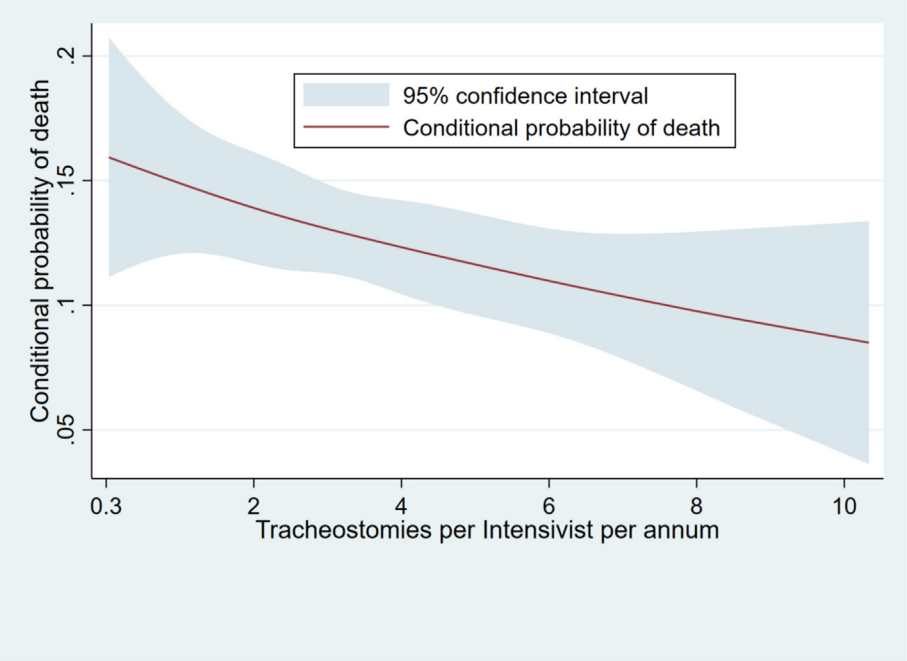

Fig. 3. Case fatality versus TPI. TPI: tracheostomy per intensivist.

linear for patients with respiratory diagnoses with the lowest risk of death observed at a TPI value of 10.3. The association was positive linear, with lowest probability of death at a TPI value of 10.3 for patients who were frail (CFS: 5–8) (10.79% [95% CI: 0.00%–27.98%]) and for diagnostic subgroups such as nontrauma (7.87% [95% CI: 3.17%–5.27%]) and nontraumatic brain injury (7.97% [95% CI: 3.35%–12.56%]) (Table S3). All the other subgroups had a U-shaped association similar to the primary outcome with the lowest risk of death observed with a TPI value between 0.04 and 10.3 (Supplementary Figures S5-14).

4. Discussion

4.1. Key findings

This study demonstrated a linear volume–outcome relationship between volume of tracheostomies, as measured by TPIs and hospital case fatality, with lower case fatality at higher TPI values. The lowest adjusted case fatality occurred when the TPI value was 10.3, with higher case fatality at lower values of TPI. The secondary outcomes of ICU length of stay, hospital length of stay, and nonhome discharge all had nonlinear associations with case fatality.

4.2. Comparisons with literature

A steady decline reported in the volume of tracheostomies being performed for ICU patients has been consistently reported in the literature. A large observational study from the USA reported an increase in the incidence of tracheostomies in the ICU by nearly 200% between 1993 and 2002 for prolonged mechanical ventilation.[31] Another large observational study from the USA from 1993 to 2012 reported an initial rise in the number of tracheostomies performed until 2008, subsequent to which there has been a steady decline in the number of procedures performed.[23] A serial cross-sectional study performed using datasets from the USA reported a decline in the rate of tracheostomies performed between 2002 and 2017 for respiratory failure.[32] Whilst our study spanned only a 5-year period and did not report a substantial decline in tracheostomy numbers in that time, it is important to note that the decline has been substantiated in the literature reported from Australian ICUs also.[26]

The overall case fatality in our study (8.5%) was lower than those reported in other studies which reported on ICU and hospital mortality which ranged from 10% to 40%.[24,26,33] The reasons for this variation could be attributed to differences in models of care, advances in respiratory therapies, patient selection, and ventilatory management strategies.

To the best of our knowledge, an evaluation of volume–outcome relationships between TPI and clinical outcomes such as ours has not previously been reported in the literature. With the decline in the number of tracheostomies being managed in ICUs, the nature of any volume–outcome relationships that may exist becomes increasingly important. Our data suggest that, as in many other circumstances in health care, there is a significant negative association between volume and case fatality, i.e, a higher volume associated with lower case fatality.

However, our findings could also be influenced by systematic biases due to the limitations of retrospective studies. The Australia and New Zealand Intensive Care Society APD has very limited treatment data: neither does it has data on surgical versus percutaneous tracheostomy insertion, nor does it have information on patient selection for tracheostomy. All these factors, and other unknown factors, may potentially have led to biased results.

Furthermore, it is possible to interpret the need for tracheostomy as a surrogate marker of illness severity. Mortality from the tracheostomy procedure itself is a very rare event, which may be driven by factors other than tracheostomy management.[16] Thus, the volume–outcome relationship demonstrated in our study may be related to more severely ill patients having better outcomes in higher-volume centres rather than tracheostomy management *per se*.

4.3. Study implications

Whether the decline in tracheostomy volumes in ICUs was due to changes in patient selection, newer strategies (for example, high-

flow nasal oxygen) to manage respiratory failure and ventilatory wean, improved multidisciplinary team management, sedation strategies, or other aspects of care, our findings highlight the need for ICUs to consider their models of care for tracheostomy insertion and management, particularly those ICUs with already low tracheostomy volumes. Healthcare systems may need to alter the referral and transfer patterns and consider establishing high-volume ICUs for tracheostomy care, with appropriate skill-mix, experience, education, and governance, if our findings are confirmed and reproduced in other settings.[34,35] Low-volume ICUs may specifically need to strengthen education, simulation, governance, and protocolisation of tracheostomy insertion and management to continue to safely care for patients requiring tracheostomies.

4.4. Study strengths and limitations

This is a registry-based study that has several strengths and limitations. The databases used for this study are recognised high-quality repositories that have been used extensively for research purposes. The exposure variable was novel and a clinically meaningful marker of volume. However, there were limitations arising from the retrospective nature of the data. Causal inferencing is not possible from this type of study, and data presented here should be viewed as exploratory and hypothesis-generating. Whilst multivariable modelling with inclusion of factors known to be associated with case fatality was performed, there is likely to be residual confounding arising from various sources. There were missing data, and the linkage between the two databases was 87.4%. The CCR provides staffing and resourcing data averaged over 12-month periods; thus, these may not always have been representative of the staffing and resourcing levels in the ICU during each patient's ICU admission. Data on open surgical versus percutaneous dilatation tracheostomy techniques were not available for this study. This is a highly relevant limitation as surgical tracheostomies are known to be associated with higher complication rates such as site infection.[21,36]

5. Conclusions

There is a linear volume–outcome relationship between tracheostomy and case fatality for ICU patients requiring insertion of tracheostomy with the lowest case fatality observed at higher TPIs per annum. The TPI value was also associated with significant differences in other outcomes such as ICU and hospital lengths of stay and nonhome discharge.

CRediT authorship contribution statement

Prashanti Marella: conception, design, data acquisition, interpretation, and manuscript—first draft and editing.

Mahesh Ramanan: conception, design, analysis, visualisation, interpretation, supervision, manuscript editing.

Alexis Tabah: data acquisition and manuscript revision.

Kevin B Laupland: data acquisition and manuscript revision.

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Conflict of interest

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

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Data availability

The data cannot be shared publicly due Institutional ethics, privacy and confidentiality regulations as per the Australia and New Zealand Intensive Care Society Centre for Outcome Research Evaluation data access and publication policy.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ccrj.2024.12.002.

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