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Risk-adjusted hospital clinical management issue rates using data from the Victorian Audit of Surgical Mortality

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assurance, audit, deviation, quality, risk, safety, surgery.

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Abstract

Background: In recent years, there has been a concerted drive for an increase in public reporting of hospital-level outcomes as a means of identifying strategies to improve patient safety. Surgical care, as a high-risk area of medical practice, has come under sharp scrutiny. This study uses data from the Victorian Audit of Surgical Mortality (VASM) in conjunction with data from the Victorian Admitted Episode Dataset to compare hospital rates of clinically identified serious clinical management issues that were definitely or probably preventable and caused or contributed to the death of the patient who would otherwise be expected to survive.
Methods: Cases where the date of death was between 1 July 2015 and 30 June 2017 that completed the full VASM audit process were extracted from the VASM database and combined with data extracted from the Victorian Admitted Episode Dataset, where a surgical admission occurred in the same time period. A logistic regression model was used as a method of indirect standardization to derive the probability of preventable clinical management issues, which was then used to calculate the standardized incident rate for all Victorian surgical hospitals. Hospitals were compared by plotting the standardized incident rates on three funnel plots.
Results: There were five hospitals (8.3%) of the 60 that deviated significantly from the state-wide rate of 0.00012.
Conclusion: The risk adjustment model identified several hospitals that may have a systematic issue which warrant further clinical quality assurance investigation.

Introduction

In recent years, there has been a concerted drive for an increase in public reporting of hospital-level outcomes.[1] These outcomes inform quality assurance management and the development of strategies to improve patient safety outcomes. Surgical care, as a high-risk area of medical practice, has come under sharp scrutiny.

One method for assessing the quality of patient care has been to compare the standardized incident rate (SIR) across hospitals, to identify those that fall more than 2 or 3 SD above or below the state-wide mean.[2] Hospitals that deviated from the state-wide rate can then be assessed to determine the reason for their deviation.

This method of comparing hospital SIRs is imperfect because the outcome being measured, such as mortality, is a proxy for the true outcome of interest – preventable mortalities. Whilst standardization methods help identify hospitals that experience a greater number of mortalities than expected, factors other than the patient's medical management, which are not included in the standardization, may contribute to so-called false discovery.[3] This study attempts to address these issues by using data from the Victorian Audit of Surgical Mortality (VASM) in conjunction with data from the Victorian Admitted Episode Dataset (VAED). Using the two data sets, this study aims to compare hospital rates of clinically identified serious clinical management issues (CMIs) that were definitely or probably preventable and caused or contributed to the death of the patient who would otherwise be expected to survive.

The VASM is a single-blinded peer review audit designed to highlight adverse trends and system and process errors that may affect the delivery of safe and effective surgical care.[4,5] The VASM investigates deaths that occur during an admission where a patient was under the care of a surgeon or where a patient undergoes a surgical procedure in their final admission to hospital. All 75 public and 42 private surgical hospitals in Victoria participate in the VASM allowing for the peer review of all surgical mortalities in Victoria. The VASM audit process comprises two levels of peer review. All cases that meet the VASM inclusion criteria undergo a first-line assessment which involves a surgical assessor reviewing the case information provided by the treating surgeon on a standardized surgical case form (SCF). The first-line assessor can close the case or recommend it undergo a second-line assessment (SLA), which involves a review of the patient's de-identified case notes and the SCF. An SLA may be recommended due to the unexpected death of a patient, insufficient information on the SCF or the belief that errors have been made which contributed to the patient's death.[6] Both the first-line and second-line assessors are from the same surgical specialty but from a different hospital as the treating surgeon and are blinded to the identity of the treating surgeon, hospital and patient.

Originating in 1979, the VAED is a comprehensive data set of the causes, effects and nature of the illnesses reported by the health services in Victoria maintained by the Department of Health and Human Services (DHHS).[7] The VAED collects a minimum set of data for each admitted patient episode to any hospital in Victoria (both public and private). Among other things, it records the diagnoses that the patient was treated for, with appropriate flags for whether these conditions were present at the time of admission or they were acquired during the inpatient episode. It also records the procedures the patient underwent during the admission. Reporting of all admissions to VAED is government requirement and is therefore considered to be highly accurate and free of missing data.[7]

Methods

This study is a retrospective observational study. Cases were identified in the VASM data set that underwent the audit process where the date of death was between 1 July 2015 and 30 June 2017. The cases were joined with the data extracted from the VAED, where a separation from a surgical episode occurred in the same timeframe, and an Australian Refined Diagnosis Related Group (ARDRG) code with a second and third character range 01–39.[8] Maternity admissions, birth admissions and posthumous organ procurement were excluded from the VAED for analysis as they do not fit the VASM criteria. Data between the VASM and VAED were joined by matching the hospital where the patient died plus three or more identifiable variables including unit record medical number, date of birth, admission date, date of death and gender.

Statistical analysis

Indirect standardization was achieved as a form of risk adjustment by using a multivariate logistic regression model to derive the probability of a serious preventable CMI for individuals, as determined by the set of covariates deemed to be clinical predictors.[2] This risk adjustment is necessary in order to account for patient fragility as not all serious preventable CMIs will result in death. The probabilities were summed over all the surgical patients being treated by each hospital to calculate the expected number of serious preventable CMIs. This number was then contrasted with the observed number of serious preventable CMIs by calculating the SIR observed number of events over the expected number of event times the state-wide event rate.

An orthogonal piecewise polynomial splines were used to fit age in the model. The variables deemed clinically relevant to investigate were admission type, patient age, patient gender, hospital region, surgical specialty, number of operations performed and transfer status. Only variables that were statistically significant at $P < 0.05$ level were included in the final logistic model.

The SIR for each hospital was plotted on funnel plots. Funnel plots are a standard tool in meta-analysis used as a graphical tool to check for any relationship between effect estimates and their precision as a way of detecting possible publication bias. However, these have been modified for an easily visualized graph for comparing hospital health outcome performance.[2] The modified version is a scatter plot with the SIR on the y-axis and the total number of surgical patients treated at a hospital on the x-axis. On the scatter plot, 95% (2 SD) and 99.8% (3 SD) control limits are superimposed.

Stata 15.0 (StataCorp, College Station, TX, USA) was used for the logistic regression model with the splingen function to generate the splines. The funnelcompar module was used to produce the funnel plots.

Results

There were 3419 cases reported to the VASM where the date of death was between 1 July 2015 and 30 June 2017. Of these 71.7% (2453/3419) had completed the full audit process. A further 18.7% (641/3419) were classified as terminal care admission and not auditable by the VASM. Only 4.8% (164/3419) were still under review with the final 4.7% (161/3419) of cases could not be audited as they did not meet the criteria or were lost to follow-up due to extensive compliance time lag. Among the 2453 cases that completed the full audit process, first-line and second-line assessors identified that 9.3% (229/2453) of cases had a serious preventable CMI.

There was a match rate of 87.2% (2140/2453) of cases that completed the VASM audit process and those in the VAED. These cases were associated with 60 Victorian hospitals. For the cases with an identified serious preventable CMI, the match rate was 79.9% (183/229). Table 1 details the characteristics of patients with and without a serious preventable CMI.

Table 2 details the characteristics of the final logistic regression model for serious preventable CMIs. The odds of a serious preventable CMI are 48.1% (odds ratio 0.509, $P < 0.001$, 95% CI 30.6–62.6%) lower in elective admission compared to emergency admissions. The odds of a serious preventable CMI were 65.6% (odds ratio 1.656, $P = 0.01$, 95% CI 10.5–148.2%) higher in metropolitan compared to rural hospitals.

To interpret the effect of the orthogonal splined age function, we plotted the odds ratio for age in Figure 1.

Figure 1 shows a line graph of the odds ratio by age with a red horizontal line showing an odds ratio of 1 for reference. The blue line shows the odds ratio for the spline age function while the dark red line shows the odds ratio for age as a polynomial function.

Table 1 Characteristics of serious preventable CMIs for patients with a surgical episode

Variable	With serious preventable CMI	Without serious preventable CMI	*P*-value
Admission type			
Emergency admission	44.8% (82/183)	38.1% (576 477/1 514 598)	0.199
Other emergency	4.4% (8/183)	4.4% (65 983/1 514 598)	
Statistical	0.5% (1/183)	0.2% (3377/1 514 598)	
Elective	50.3% (92/183)	57.4% (868 761/1 514 598)	
Hospital region			
Rural	15.3% (28/183)	22.4% (339 652/1 514 598)	0.021
Metropolitan	84.7% (155/183)	77.6 (1 174 946/1 514 598)	
Specialty			
Neurosurgery	9.3% (17/183)	2.4% (36 043/1 514 598)	<0.001
Vascular surgery	11.5% (21/183)	1.1% (17 393/1 514 598)	<0.001
Orthopaedic surgery	14.8% (27/183)	12.8 (193 968/1 514 598)	0.430
Ophthalmology	3.8% (7/183)	3.2% (48.406/1 514 598)	0.628
ENT	1.6% (3/183)	6.3% (95 897/1 514 598)	0.009
Cardiothoracic surgery	14.8% (27/183)	0.9% (13 911/1 514 598)	<0.001
Plastic surgery	3.8% (7/183)	6.2% (94 653/1 514 598)	0.175
General surgery	37.2% (68/183)	13.5% (203 968/1 514 598)	<0.001
Urology	9.8% (18/183)	7.3% (110 294/1 514 598)	0.184
Gynaecology	1.1% (2/183)	4.8% (72 127/1 514 598)	0.020
Age (mean (SD))	73.0 (24.4)	50.8 (15.1)	<0.001
Number of operations (mean (SD))	2.1 (3.8)	1.0 (2.5)	<0.001
Transferred			
Yes	19.1% (35/183)	6.1% (92 690/1 514 598)	<0.001
No	80.9% (148/183)	93.9% (1 421 908/1 514 598)	
Gender			
Male	53.0% (97/183)	49.2% (744 566/1 514 598)	0.581
Female	47.0% (86/183)	50.8% (770 006/1 514 598)	
Intersex	0.0% (0/183)	0.0% (26/1 514 598)	

CMI, clinical management issue; ENT, ear, nose and throat.

Table 2 Logistic regression model for serious preventable CMIs

		Logistic regression		
Patient risk factor	Prevalence (%)	Odds ratio	*P*-value	95% CI
Admission type				
Emergency admission	38.06% (576 559/1 514 781)	1		
Other emergency	4.36% (65 991/1 514 781)	0.528	0.09	0.255–1.095
Statistical	0.22% (3378/1 514 781)	1.098	0.93	0.152–7.961
Elective	57.36% (868 761/1 514 781)	0.509	<0.001	0.374–0.694
Hospital region				
Rural	22.43% (339 680/1 514 781)	1		
Metropolitan	77.58% (1 175 101/1 514 781)	1.656	0.01	1.105–2.482
Specialty				
Neurosurgery	2.38% (30 060/1 514 781)	4.460	<0.001	2.673–7.440
Vascular surgery	1.15% (17 414/1 514 781)	6.224	<0.001	3.918–9.888
Orthopaedic surgery	12.81% (193 995/1 514 781)	1.255	0.29	0.826–1.905
Cardiothoracic	0.92% (13 938/1 514 781)	3.108	<0.001	9.590–22.130
Plastic surgery	6.25% (94 660/1 514 781)	0.577	0.16	0.266–1.250
General surgery	13.47% (204 036/1 514 781)	5.007	<0.001	3.688–6.799
Urology	7.28% (110 312/1 514 781)	1.214	0.45	0.739–1.994
Gynaecology	4.76% (72 129/1 514 781)	0.255	0.07	0.057–1.128
ENT	6.33% (95 900/1 514 781)	0.296	0.04	0.092–0.952
Ophthalmology	3.20% (48 413/1 514 781)	0.773	0.52	0.355–1.686
Age (per 10 years)				
Age spline 1	100%	3.235	<0.001	2.427–4.311
Age spline 2	100%	0.631	<0.001	0.499–0.798
Age spline 3	100%	0.545	<0.001	0.428–0.694
Intercept	100%	<0.001	<0.001	<0.001–<0.001

CMI, clinical management issue; ENT, ear, nose and throat.

Figure 1 shows that the spline function is quite similar to the polynomial function, with the largest separation occurring in the high age ranges where the number of patients becomes lower.

Initially, an increase in age results in a decrease in the odds of a serious preventable CMI compared to patient younger than 1 year old. Once a patient reaches the mid-50s, the odds increase to over

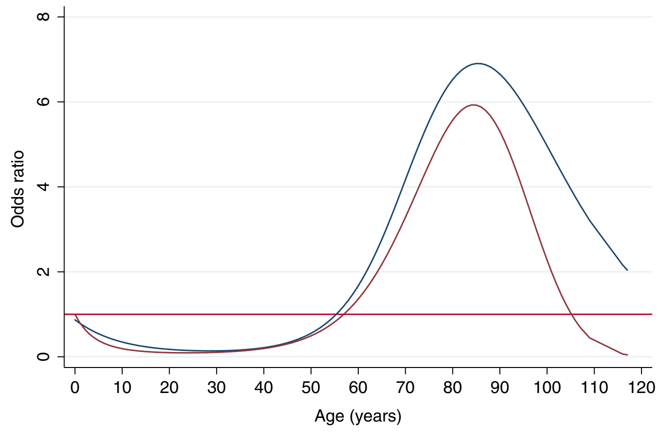

Fig. 1. Odds ratio for age in final logistic regression model for serious preventable clinical management issues. ——, Age (spline); ——, age (poly).

1, showing that the patient has higher odds of a serious preventable CMI compared to a patient younger than 1 year old. The odds peak in the mid-80s before decreasing as the patient gets older. These findings are clinically sound as the highest risk patients are the very young and the old; however, past a certain age, the risk associated with surgery becomes so high that the situations where surgery will be performed becomes more limited, therefore the odds of serious preventable CMIs would be expected to decrease after this point as the outcomes become more expected.[4,5]

Table 3 shows the number of observed serious preventable CMIs, the raw rate of serious preventable CMIs, the expected number of serious preventable CMIs and the calculated SIR for each hospital. This showed 13 hospitals with an increased SIR and 17 hospitals with a decreased SIR compared to the original raw rate of serious preventable CMIs.

Figures 2–4 plot the SIR of serious preventable CMIs for each Victorian hospital as a scatter plot with the 95% (2 SD) and 99.8% (3 SD) exact control limits surrounding the Victorian event rate plotted as a horizontal red line for the fiscal years 2015–2017, 2015–2016 and 2016–2017, respectively.

In Figure 2, hospitals 34, 2 and 24 may need investigation according to the VASM definitions. Hospital 9 falls outside the 3 SD limits marking it for automatic investigation. Hospital 19 falls between the 2 and 3 SD below the state-wide average marking it as a potential hospital to be learnt from.

In the 2015–2016 fiscal year, hospital 2 fell 3 SD above the state-wide event rate, while hospitals 29, 34, 24 and 37 fell 2 SD above the state-wide event rate. While in the 2016–2017 fiscal year, hospital 9 fell 3 SD above the state-wide event rate, hospital 34 fell 2 SD above the state-wide event rate.

Table 3 SIR per Victorian hospital

	Serious preventable CMIs			
Hospital ID	Observed	Expected	SIR	Raw CMI
1	11	9.79150	0.00014	0.00017
2	6	2.22026	0.00033	0.00020
3	15	9.12607	0.00020	0.00029
4	0	1.01643	0.00000	0.00000
5	9	7.95446	0.00014	0.00017
6	1	0.54423	0.00022	0.00014
7	2	1.77610	0.00014	0.00009
8	1	1.17498	0.00010	0.00007
9	22	8.46551	0.00031	0.00032
11	10	5.35001	0.00023	0.00035
12	2	1.44913	0.00017	0.00004
13	3	3.91288	0.00009	0.00010
14	0	1.14247	0.00000	0.00000
15	8	6.48208	0.00015	0.00014
16	0	2.04745	0.00000	0.00000
17	14	10.24272	0.00017	0.00021
18	0	1.62820	0.00000	0.00000
19	0	5.77716	0.00000	0.00000
20	6	6.97445	0.00010	0.00014
21	0	0.47071	0.00000	0.00000
22	0	1.52311	0.00000	0.00000
23	0	2.02123	0.00000	0.00000
24	5	2.05626	0.00029	0.00016
25	4	4.83335	0.00010	0.00007
26	0	0.68000	0.00000	0.00000
27	7	6.49200	0.00013	0.00013
28	0	1.02059	0.00000	0.00000
29	2	0.82085	0.00029	0.00023
30	0	0.75297	0.00000	0.00000
31	7	7.11093	0.00012	0.00013
32	0	1.11677	0.00000	0.00000
33	2	2.12284	0.00011	0.00008
34	4	1.16912	0.00041	0.00028
35	1	3.14448	0.00004	0.00004
36	0	0.96825	0.00000	0.00000
37	7	4.70552	0.00018	0.00023
38	0	0.07828	0.00000	0.00000
39	0	1.42812	0.00000	0.00000
40	1	2.74780	0.00004	0.00003
41	0	0.60665	0.00000	0.00000
42	12	9.50351	0.00015	0.00020
43	0	1.47993	0.00000	0.00000
44	9	7.92412	0.00014	0.00017
45	0	1.78176	0.00000	0.00000
46	1	1.85346	0.00007	0.00005
47	0	2.70051	0.00000	0.00000
48	5	3.21462	0.00019	0.00024
49	0	0.45524	0.00000	0.00000
50	0	2.58403	0.00000	0.00000
51	1	2.53023	0.00005	0.00007
52	0	1.15428	0.00000	0.00000
53	0	0.75399	0.00000	0.00000
54	0	3.33075	0.00000	0.00000
55	0	0.38177	0.00000	0.00000
56	2	5.33448	0.00005	0.00006
57	0	0.66542	0.00000	0.00000
58	0	0.68215	0.00000	0.00000
59	1	2.36819	0.00005	0.00006
60	2	1.35566	0.00018	0.00028

CMI, clinical management issue; SIR, standardized incident rate.

Discussion

The VASM exists as part of the Australian and New Zealand Audit of Surgical Mortality; unique in the world as the only national peer-reviewed audit of all surgical mortalities. This analysis is the first attempt to combine the outcomes of the peer-reviewed assessments with administrative data for the purpose of monitoring qualitative assurance.

The VASM recommends further investigations performed by the hospital and the DHHS for any hospital that has an SIR more than

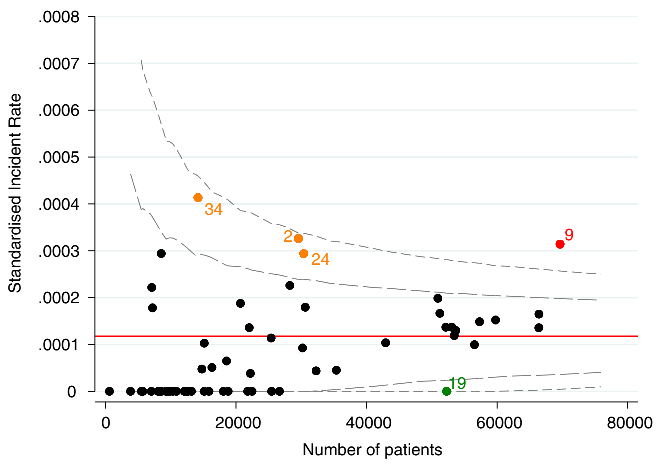

Fig. 2. Funnel plot of standardized incident rate for cases with a potentially preventable clinical management issues during the 2015–2017 fiscal year (flag 0.2% and 5% significant contours above state-wide mean 0.00012). ●, Hospital; ——, 95% confidence limit; – – -, 99.8% confidence limit.

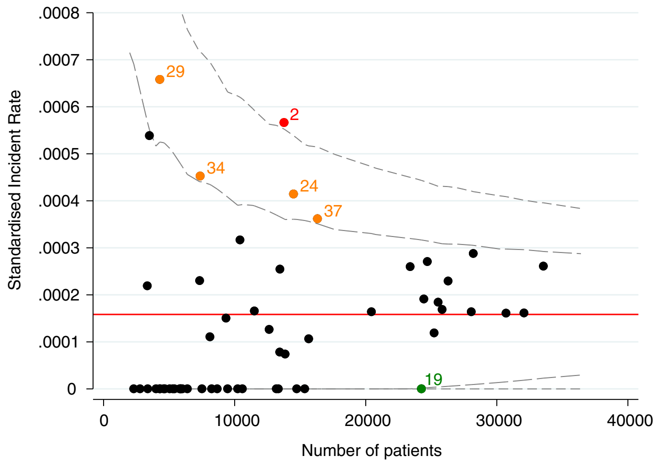

Fig. 3. Funnel plot of standardized incident rate for cases with a potentially preventable clinical management issues during the 2015–2016 fiscal year (flag 0.2% and 5% significant contours above state wide mean 0.00010). ●, Hospital; ——, 95% confidence limit; – – -, 99.8% confidence limit.

2 SD above the state-wide mean in consecutive years or more than 3 SD above the state-wide mean in any individual year. The results indicate that hospitals 2 and 9 may have had anomalous years during 2015–2016 and 2016–2017, respectively, and they should be investigated to determine if there have been any changes during this period that could account for the differences in result. Hospital 34 flags in both fiscal years indicating that there may be a systematic issue that requires investigation.

The VASM provides all Victorian hospitals and the state government through Safer Care Victoria with yearly reporting of the serious CMIs identified at their hospital. This information along with other aggregated performance indicators provided by the VASM can be utilized by the hospital to target areas of clinical practice for quality assurance purposes. Further investigation is required to

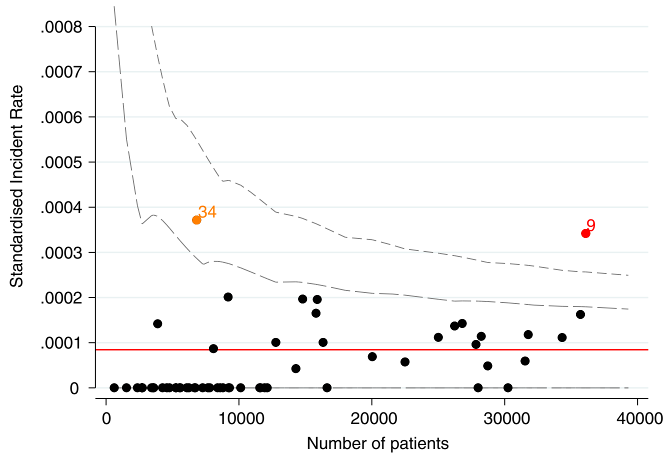

Fig. 4. Funnel plot of standardized incident rate for cases with a potentially preventable clinical management issues in the 2016–2017 fiscal year (flag 0.2% and 5% significant contours above state wide mean 0.00014). ●, Units; ——, significant at 5%; – – -, significant at 0.2%.

describe the quality assurance strategies implemented by the hospitals to redress the serious CMIs identified by the VASM.

The logistic regression model identifies areas of focus for DHHS or hospital quality assurance investigations. Patients at highest risk of a serious preventable CMI are older than 60 years of age and are emergency admissions at metropolitan hospitals for vascular surgery, general surgery, neurosurgery or cardiothoracic surgery. It should be noted that the regression model identifies risk factors for serious preventable CMIs that results in death. As such, they may be representing differences in the fragility of patients rather than an inherent difference in the rate of serious preventable CMIs. This explains the presence of age as a highly significant risk factor in our model as a CMI that would be fatal to an elderly patient may be more survivable to a young healthy patient.

If the no risk adjustment is performed and funnel plots are instead generated using the raw incidence rate for the 2015–2017 period, then hospitals 11, 3 and 9 would flag as being 3 SD above the state-wide mean, hospital 17 would flag as 1 SD above the state-wide mean and hospital 19 as 1 SD below the state-wide mean. This leaves only one hospital, hospital 9, flagging above the state-wide mean in both the raw and standardized rate. This difference can be attributed to the difference in case mix between different Victorian hospitals and highlights that there is likely to be serious preventable CMIs that do not cause death and therefore cannot be detected by the VASM.

Limitations

Identification of serious preventable CMIs comes from a mortality audit and as such these results are only the rate of serious preventable CMIs that caused or contributed to death. The rate of serious preventable CMIs that did not result in death cannot be calculated given the available data sources.

It should be noted that the VAED captures up to 40 diagnosis codes and up to 40 procedures that were administered during an episode. This information is used to code an ARDRG which is often useful in analysing episodes with similar conditions. However, there is very limited information in the VAED that indicates the severity of the condition which can be useful for risk adjustment. A qualitative analysis of the themes of CMIs may identify further clinical predictors to improve the accuracy of our model.

The VAED uses a slightly different definition of surgical care to the VASM data set. The VAED identifies patients as being surgical based on the type of procedure performed as determined by the ARDRG codes for the patient admission. However, the VASM data set identifies patients as being surgical based on the type of procedure performed and whether a surgeon performed the procedure. This means that some procedures performed by a proceduralist such as a cardiologist or radiologist would appear in the VAED but not in the VASM data set. This could lead to an over- or underestimation of the hospitals' SIR if the hospital has a lower or higher rate on proceduralist's performing procedures.

Conclusion

The Victorian state-wide SIR for serious preventable CMIs from 1 July 2015 to 30 June 2017 was 0.00012. There were five hospitals that deviated significantly from the state-wide rate and require potential further investigation. The process outlined in this study allows for the comparison of the rate of serious preventable CMIs between hospitals with different case mixes. If the analysis was performed on the unadjusted raw serious preventable CMI rate, hospitals with higher proportions of fragile patients would be more likely to flag as an outlier due the increased probability that any given serious preventable CMI would result in death of the patient. Comparing the SIR for serious preventable CMIs instead of the raw serious preventable CMI rate allows the VASM to compare Victorian hospitals irrespective of case mix. This analysis enables all Victorian hospitals to carry out a systematic and robust quality assurance approach to eliminate potential CMIs to improve patient safety and overall patient outcomes.

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Conflicts of interest

None declared.

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