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PII: S1743-9191(17)31502-9

DOI: 10.1016/j.ijsu.2017.12.023

Reference: IJSU 4362

To appear in: *International Journal of Surgery*

Received Date: 25 August 2017

Revised Date: 6 December 2017

Accepted Date: 20 December 2017

Title

Major inpatient surgeries and in-hospital mortality in New South Wales public hospitals in Australia: a state-wide retrospective cohort study

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Word count for the abstract: 268 words

Word count for the text of manuscript: 2,862 words

Running title: In-hospital surgical mortality

Conflict of Interest: None

Acknowledgements

We appreciate the NSW Health Department for providing the APDC data, and Luis Furuya-Kanamori and Alex Peng for selecting the ICD-10 AM procedure codes. The study sponsors had no further role in the study design, data collection, analyses, interpretation of results, writing of the article, or the decision to submit it for publication. AC Is funded by an Australian National Health and Medical Research Council Senior Research Fellowship (#1058878).

Title

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Abstract

Background: Surgical interventions save lives and are important focus for health services research worldwide. Investigating variation in postoperative mortality may improve understanding of unwarranted variations and promote safety and quality in surgical care. We aimed to evaluate trends of in-hospital mortality rates among adult inpatients receiving major elective surgeries and determine the variation in mortality among New South Wales (NSW) public hospitals.

Materials and Methods: In this study, we used the all-inclusive population-based NSW Admitted Patient Data from July 2001 to June 2014. We retrospectively included adult patients aged 18+ years receiving Abdominal Aortic Aneurysm (AAA) repair, Peripheral bypass, Colorectal surgeries, Joint replacement, Spinal surgeries, or Cardiac surgeries. The primary outcome was in-hospital mortality for selected surgeries. Changes in mortality rates over time and hospital standardised mortality rates were modelled using multivariate logistic regression models adjusting for case-mix factors.

Results: Over 13-year study period, the in-hospital mortality rates declined annually by 6.4% (95% Confidence Interval (CI): 4.3, 8.4) for Colorectal surgery by 5.7% (95%CI: 2.0, 9.3) for Joint replacement and by 4.2% (95%CI: 1.9, 6.4) for Cardiac surgery. After controlling for patient-level factors, little variation was observed among hospitals for in-hospital mortality. There was a greater variability for cardiac surgery compared with the other surgical groups but no outlier hospital was consistently associated with significantly higher than expected mortality rate.

Conclusions: Mortality has declined for major surgeries in the past 15 years. There was some variation among hospitals regarding in-hospital mortality that was mostly explained by patients demographic and admission characteristics. Our findings are reassuring for patients and contribute to knowledge that can help further improve surgical care.

Introduction

Number of inpatient surgeries have been increasing over years in Australia (1,2) and elsewhere in the world (3,4). Between 2009–10 and 2013–14, elective (non-emergency) admissions involving surgeries increased by 2.3% per annum (2). In 2013–14 years there were almost 2.1 million elective admissions involving surgery in Australia's hospitals (2). Such increase may reflect the necessity to provide surgical care for aging population and address unmet needs (4-6).

Many elective surgeries are invasive and complex procedures conducted for chronic conditions in elderly patients and can lead to death in the hospital (7). Postoperative mortality affects benefit versus harm equation and is widely recommended to measure quality of surgical care (8,9). Some studies reported reduction in postoperative mortality in Australia and USA over recent years (10,11), however, presence of variation in mortality rates among hospitals indicates opportunities for improving quality of surgical care (12,13). It is critical to understand if such variation would be predicted by differences in case-mix factors, postoperative care policies across different hospitals, or by chance alone.

Several prior studies evaluated variation among hospitals and restricted analysis to a single type of surgery (14-18). Ghaferi et al identified higher-mortality hospitals in the US were associated with worse outcomes across five selected surgery groups compared with their lower-mortality counterparts (19). If such high-mortality hospitals exist then they can be targeted for research and selected for further investigation of perioperative practices and policies to reduce surgical mortality.

We aimed to determine if hospital with elevated postoperative mortality risk for one type of surgery might be associated with elevated risk for other types of surgeries because its surgical patients may share the same standard perioperative facilities and care pathways. We also aimed to evaluate trends in postoperative mortality over time in relation to volume of major elective surgeries, and explore the extent to which postoperative mortality will vary between hospitals for major surgical procedures.

Methods

Data sources

The NSW Admitted Patient Data Collection (APDC) is a complete census of hospital separations maintained by NSW Health Department (20). It covers all public, private and repatriation hospitals and private day procedures centres in NSW. Medical reasons for hospital admission were coded at the time of separation using the Australian modification of ICD-10 (ICD-10-AM) (21). Based on the data use agreement with NSW Health Department, for each de-identified separation record we extracted the patient's age, sex, marital status, post codes of usual residence, urgency of admission, hours in intensive care, up to 53medical diagnoses, up to 50 surgical procedures, separation mode, and hospital sectors, to conduct this multi-centre retrospective cohort analysis. This work has been reported in line with the STROCSS criteria (22). Ethics approval was sought from the relevant Science & Medical Delegated Ethics Review Committee (#2016/030)

Study population

We used the ICD-10 AM codes for primary procedures to select surgeries of interest from the APDC data from July 2001 to June 2014, and categorised them into 6 major groups, i.e., Abdominal Aortic Aneurysm (AAA) repair (resection of abdominal aorta with anastomosis or replacement); Peripheral bypass (reroute the blood supply flow around the peripheral artery); Colorectal surgeries (incision, resection or anastomosis of the large intestine); Joint replacement (arthroplasty of knee and hip); Spinal surgeries (laminectomy and spinal fusion); and Cardiac surgeries (open chest procedure on the valves or septum or coronary artery bypass graft) (see Supplementary Table 1).

Although inclusion of private hospitals would most accurately reflect shifts in volume between public and private hospitals, the exact private hospital identifier was not available; hence, we restricted our analysis on public hospitals. We considered NSW residents aged 18 years and over who were admitted to public hospitals in NSW for elective surgeries.

Outcome

We focused on in-hospital mortality. While 30-day mortality might be more sensitive to changes in quality and perhaps more meaningful for patients given the leverage of data linkage via unique patient identifier, in-hospital mortality can be easily derived using de-identified hospital records as a screening practice to inform quality improvement (8), with substantially high agreement (Kappa: 81-89%) with 30-day mortality to identify outliers (23). Similar to previous studies (13-18), we considered the all-cause in-hospital mortality rate as our study outcome, which was available to us and case-specific to selected surgical procedures. We used the discharge mode to define in-hospital deaths when a patient died during the episode of care; and used the total number of patients undergoing the relevant surgeries as the in-hospital mortality denominator.

Confounders of interest

We treated financial year of separation as continuous and categorised age group in years (i.e. 18-44, 45-64, 65-84, 85 years and over); sex as male or female; marital status as married/defacto or single; socioeconomic status as 1st (most disadvantaged), 2nd, 3rd, 4th, or 5th (least disadvantaged)quintile using the postcode based Index of Relative Socio-Economic Disadvantage (24); private insurance as yes, or no; intensive care as yes or no; palliative care as yes or no using the ICD-10AM diagnosis code of Z51.5(21); comorbidity as mild(total score of 0), moderate(total score of 1 or 2), or severe (total score ≥2) using the Charlson index score(25); hospital characteristics as principal referral (category with >20,000 separations, and Regional hospitals with >16,000 separations per annum), major city (category with >5,000~10,000 separations in general), or other peer groups(e.g., medium district, small community, and unpeered hospitals, with less than 5000~10,000 separations in general),using the classification system developed by the Australian Institute of Health and Welfare (26) for capturing hospital characteristics in relation to remoteness and hospital size. A separate category was included for missing values.

Statistical analysis

We carried out all analyses using SAS version 9.3 (SAS Institute, 2008). We derived surgery-specific case sets comprising patients undergoing primary procedures from the selected major surgical groups. We calculated numbers and proportions of patients for each surgery group. Because perioperative care may differ across hospitals due in part to different case-mixes and nature of service provided (26), we considered variation of in-hospital mortality rates between hospitals. We first use a null mixed-effect logistic regression model with hospitals included as the random intercept, and then subsequent models adjusted for confounders of interest to compare rates between hospitals considering potential patient clustering within hospitals. Model-derived intraclass correlation (ICC) was used to determine to what extent the mortality rate varies across different hospitals (27). In case of lacking heterogeneity across hospitals, we used the simpler logistic regression without mixed effect to model the binary in-hospital deaths, adjusted for age group, sex, comorbidity, socioeconomic status, marital status, private insurance, palliative care, intensive care, financial year, and hospital peer group. We used the C-statistics to evaluate the model predicative ability (28). Based on model-derived C-statistic >0.7, we consider a model acceptable and reasonable (28). For comparison between hospitals, we indirectly adjusted for mortality rate using the ratio of observed to expected deaths, and plotted the adjusted mortality rate in relation to hospital-specific volume of surgeries to create the funnel plots with the 95% and 99.8% control limits around the overall in-hospital mortality rate (29).We also created the funnel plots for crude in-hospital mortality rate. Because the in-hospital deaths were rare events, we added 0.5 to all observed and expected cases for death counts ≤5 or total surgeries ≤10 to stabilise the adjusted rate (30).We calculated percentage change in adjusted mortality rate over time with financial year as the explanatory variable. We set P value <0.05 as statistically significant.

Sensitivity analysis

We further ran series of modelling for patients undergoing primary and secondary surgeries of interest, and compared the percentage change in adjusted mortality rates over time, ICC, C-Statistics, and funnel plots. Multiple ICD-10 procedures within one case were counted separately.

Results

Population characteristics

There were 1,467 AAA repairs, 1,668 Peripheral bypasses, 15,920 Colorectal surgeries, 28,062 Joint replacements, 1,032 Spinal surgeries, and 13,197 Cardiac surgeries conducted as primary procedures during the study period. The majority of patients undergoing AAA repairs, Peripheral bypasses, Colorectal surgeries, Joint replacements, and Cardiac surgeries were those aged 65-84 years, followed by 45-64-year olds; whereas Spinal surgeries was equally distributed in both age groups (Table 1). Male patients were overrepresented in AAA repair, Peripheral bypass, Colorectal surgeries, and Cardiac surgeries, but female patients accounted for more than half of the Joint replacement and Spinal surgeries (Table 1). More patients with moderate-severe comorbidities died after surgeries at the end of episode of care (Table 1). Most of these surgeries were conducted in principal referral hospitals (Table 1).

Change in mortality rates

Figure 1 shows the volume of operations and adjusted mortality rate (%) in patients undergoing selected surgeries. During the study period, a decline of volume for AAA repair and Peripheral bypass was observed in contrast with the rise of volume for Joint replacement and Spinal surgeries. The volume of Colorectal and Cardiac surgeries was fairly steady (Figure 1).

The in-hospital mortality rates per 100 patients were significantly declining over years for Colorectal surgery from 1.97 to 1.02 (by 6.4% per annum,95% Confidence Interval (CI): 4.3, 9.4), Joint replacement from 0.35 to 0.13 (by 5.7%,95%CI: 2.0, 9.3) and Cardiac surgery from 2.22 to 1.70 (by 4.2%,95%CI: 1.9, 6.4). Although not statistically significant, mortality rates marginally decreased by 2.9% per annum (95%CI: -17.6, 18.2) for Spinal surgery and increased by 1.1% (95%CI: -4.2, 6.6) for AAA repairs and 0.4% (95%CI: -5.9, 7.0) for Peripheral bypass procedures.

Hospital variation in mortality

The null mixed-effect models indicated that between-hospital variation (ICC) was negligible for AAA repair, Peripheral bypass, Joint replacement, and Spinal surgery; but explained11.5% and 7.4% of the total variance for Colorectal surgery and Cardiac surgery, respectively. After adjusting for additional patient demographic and admission characteristics, these observed variation between hospitals disappeared, that is, patient characteristics explained most of the variation in mortality. In other words, simpler models without hospital random effects were sufficient.

There was variation among hospitals regarding in-hospital mortality rates after cardiac surgery with two high-volume hospital having in-hospital mortality rate below the 95% lower control limit; whereas three hospitals above the 95% upper control limits (Figure 2). Similar variation was noted for colon and rectal surgery with five hospital outliers (above the 99.8% upper limits).The outliers with higher in-hospital mortality rate for Peripheral bypass and Joint replacement were hospitals with higher volume compared with the majority of the others (Figure 2). No outlier hospital was consistently associated with significantly higher mortality rate across different surgical procedures.

Sensitivity analysis

After a series of sensitivity analyses, the change in rates, and the model predicative ability for different surgery groups did not change (Supplementary Table 2). The unadjusted variation between hospitals for Colorectal surgeries reduced substantially (Supplementary Table 2) and all hospitals were within the 95% control limits for standardised in-hospital mortality rates (Supplementary Figure 2).

Discussion

In this large scale study we found that adjusted in-hospital mortality rates vary among the hospitals and all surgeries became low risk procedures which is consistent with previous finding of <1% in-hospital mortality rate after major elective surgeries in the Australian, England, Netherlands, and US hospitals (31). A decreasing trend in mortality was observed for Joint replacement, Cardiac and Colorectal surgeries. Our study is supported by similar patterns reported before (32-34). We believe these achievements are likely attributed to advancement in surgical techniques, patient selections or implementation of surgical care improvement programs. The in-hospital mortality remained statistically unchanged only for open AAA repair, which is done less frequently due to introduction of endovascular repair and possibly reserved for sicker patients. Because APDC data lacks clinical markers associated with elevated mortality risk (e.g., preoperative hemoglobin level, intraoperative blood loss volume, postoperative bowel ischemia) (20), we were unable to determine whether any deaths were avoidable. Nevertheless, in ideal world no elective surgical patient should die and our findings demonstrate the importance of continuing efforts to improve quality of care and support the surgical safety initiatives in Australia including staff training, adoption of safety checklist, and national standards newly developed or under development (35).

Previously the US study indicated that some hospitals might have consistent higher mortality rates across some surgical procedures in spite of different case-mix (19). Our findings did not support this result in New South Wales; the most populous state in Australia. We did not observe any hospital that has consistently worse outcomes for all major surgeries. While we observed some variability among hospitals, it was not associated with volume of surgeries. For example, hospitals with high volume of cardiac surgery appeared to have higher or lower mortality than expected. This was somewhat counter intuitive because high-volume hospitals are known to be associated with lower mortality compared with their low-volume counterparts (36). It is possible that regionalization of care is much more prevalent in Australia for sicker surgical patients (37), with more surgeries being done at regionalized and high-volume centers over time during the study period. While regionalization provides benefits including centralized resources (38), it is also associated with impediments such as distance to travel, waiting time to surgery, and logistics of bed occupancy. Improved access to surgery at regional hospitals may respond to the urgently needed surgical care for rural residents and potentially reduce post-surgical mortality. Moreover, this observed lack of volume-outcome difference could be attributed to a volume shift in case severity as our study indicates that the decrease for some surgeries in sicker patients has outpaced that for their healthier counterparts (Supplementary Table 3). For Joint replacement, with an increasing trend over time, there was a decrease in sicker patients as opposed to an increase in healthier patients over time (Supplementary Table 3). Therefore, volume of selected surgeries alone may not be an appropriate measure to reflect improved quality of care, e.g., decreased mortality. Future studies with sufficient risk adjustment of surgeon-level expertise and hospital-level perioperative process may elucidate the volume-outcome relationship further.

Our study had several limitations. First, we used administrative APDC data with predefined data fields, which limited our ability to fully consider perioperative scenarios during risk adjustment. We were unable to differentiate effects from unmeasured confounding factors or by chance alone. Ben-Tovim et al reviewed international methods for analysing in-hospital mortality rates and demonstrated appropriateness of using Australian APDC data to screen for underperformed hospitals (8). Given all risk-adjusted models produced the reasonable C statistic (approximating or greater than 0.8), a measure of performing well in predicting risk of in-hospital mortality (28), our results were somewhat robust in the current setting and suggest prevention of in-hospital surgical mortality was a more general issue rather than some hospitals performing better or worse than the others. Second, without access to perioperative information specific to individual hospitals, we only attempted to explore the variability of in-hospital mortality rates for snapshot investigation. Our findings indicate need of future investigation on surgeons' proficiency and hospital-specific perioperative care policy and programs that may influence in-hospital mortality. Third, heterogeneity between procedures within a selected surgical group may contribute in part to observed variability or invariability across hospitals. Fourth, clinical coding practice may vary across hospitals. While the study results should be interpreted with caution, such impact was deemed unlikely to explain our main findings, considering NSW Health Department has routine data quality check programs in place and the sensitivity analysis based on different case selection criteria indicates similar patterns. Fifth, we restricted our analysis on public hospitals, and were not able to control for the influence of the private and public sectors on surgical volumes, e.g., a potential shift from public to private hospitals or vice versa, hence, cautions are warranted when interpreting results across private and public sectors. Although the increase of hospital treatment in the private sectors has been faster than that in the public sectors (39), the overall demand is increasing over time, placing considerable burden to both private and public hospitals. A recent study of joint replacements reported similar surgical outcomes across public and private sectors in Australia (40). Clearly, providing high quality of surgical care will require combined efforts and strong partnerships from both sectors.

Our study adds to the evidence related to unwarranted mortality variation in elective surgeries. Facing an ageing population and ever-changing chronic disease landscapes, many specialty programs and generics have been developed, including various safety and quality guidelines such as the World Health Organizations' global initiative "Safe Surgery Saves Lives" to improve surgical care among inpatients (9). These programs may have contributed to the observed declining in-hospital mortality rates and the narrowing difference between hospitals. However, avoiding harms related to newly emerging surgical procedures requires constant update of guidelines (41). Because we observed little sign of between-hospital variations of in-hospital mortality rates after surgeries, it is important to note that patient-level variations accounted for the vast majority of total variation in postoperative mortality. This finding implies that future policy initiatives to reduce in-hospital surgical mortality and its variability between hospitals may focus on patient-centred strategies such as proper selection of patients in decision making process and enhancement in patient-surgeon communication while addressing deficiency in perioperative care.

Declining in-hospital mortality rates for some major surgeries and lack of consistent cross-surgery hospital outliers are reassuring but the efforts to reduce mortality further should not stop. Future research may target identification of good practices from best performing hospitals and integrate patient-centred strategies into perioperative care to save lives and reduce surgical harms.

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Table 1 Number (Proportion %) of in-hospital deaths for patients undergoing major surgeries in NSW public hospitals*^ⱡ

	AAA repair	Peripheral bypass	Colorectal surgeries	Joint replacement	Spinal surgeries	Cardiac surgeries
Age group (years)						
18-44	np	np	9(0.3)	np	np	11(0.7)
45-64	ns	ns	62(0.5)	ns	np	100(1.0)
65-84	106(5.6)	46(1.8)	362(1.9)	125(0.2)	ns	450(2.8)
85+	9(8.9)	11(4.0)	94(4.8)	64(1.6)	np	40(7.9)
Sex						
male	86(4.7)	42(1.6)	330(1.7)	101(0.3)	9(0.5)	324(1.6)
female	35(7.0)	23(2.0)	197(1.2)	103(0.2)	6(0.3)	277(3.4)
Comorbidities						
mild	32(2.2)	6(0.2)	113(0.5)	45(0.1)	np	110(0.7)
moderate	51(7.9)	25(2.7)	165(3.1)	90(0.9)	ns	217(2.3)
severe	38(16.6)	34(7.7)	249(3.2)	69(3.5)	8(6.0)	274(7.4)
IRSD (quintile)						
1st	35(5.8)	22(2.1)	141(1.5)	61(0.2)	np	183(2.2)
2nd	24(4.2)	9(1.1)	128(1.4)	45(0.2)	ns	141(2.3)
3rd	27(5.2)	15(1.8)	116(1.6)	47(0.2)	np	103(1.7)
4th	23(5.8)	10(1.5)	90(1.4)	39(0.2)	np	116(2.5)
5th	12(5.0)	9(1.9)	52(1.3)	12(0.1)	np	58(1.9)
Palliative care						
no	ns	ns	488(1.4)	194(0.2)	ns	593(2.1)
yes	np	np	39(18.1)	10(20.4)	np	8(57.1)
Marital status						
single	53(6.6)	24(1.4)	245(1.7)	105(0.3)	np	253(2.7)
married	68(4.4)	41(1.9)	282(1.3)	99(0.2)	ns	348(1.8)
Private insurance						
no	101(5.2)	57(1.7)	449(1.5)	182(0.2)	ns	545(2.1)
yes	20(5.2)	8(1.8)	78(1.3)	22(0.3)	np	56(2.5)
Intensive care						
no	11(1.8)	33(0.9)	176(0.6)	134(0.1)	np	62(1.9)
yes	110(6.4)	32(11.8)	351(7.1)	70(3.0)	ns	539(2.1)
Hospital peer group						
principal	ns	ns	465(1.6)	165(0.3)	ns	ns
major	np	np	29(0.9)	17(0.1)	np	np
other	no	np	33(1.0)	22(0.1)	np	np

* Numbers less than and equal to 5 were not reportable and presented with “np” signs; and relevant lowest reportable numbers were suppressed with “ns” signs.

^ Index of Relative Socio-Economic Disadvantage (IRSD) quintile comprises categories of 1st (most disadvantaged), 2nd, 3rd, 4th, or 5th (least disadvantaged) quintile.

ⱡ Unclassifiable category was not presented.

Figure 2 Variation of adjusted in-hospital mortality rates following selected surgeries in NSW public hospitals, July 2001 to June 2014

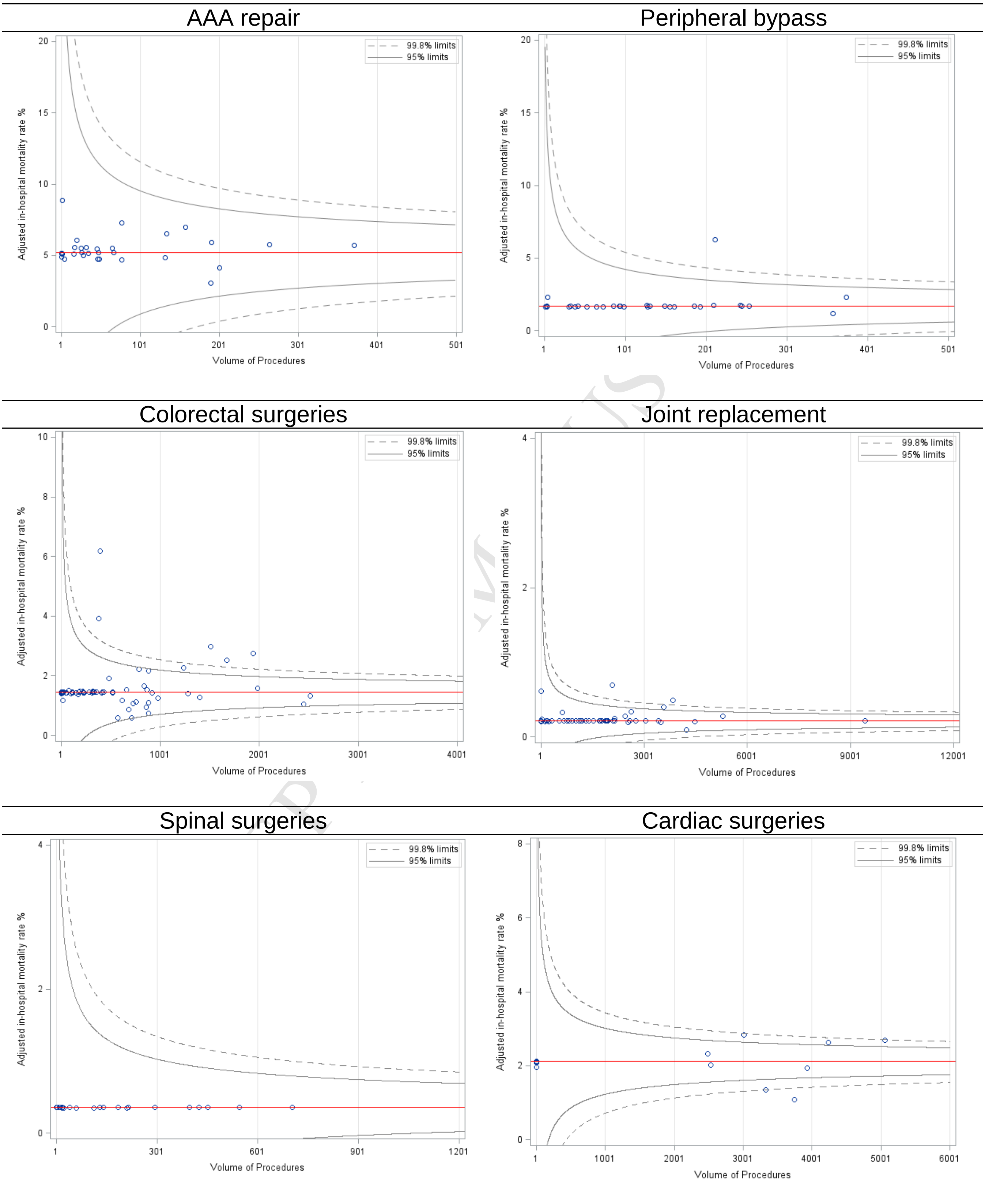

Figure 1 Volume (n) and adjusted in-hospital mortality rate (%) for selected surgeries in NSW public hospitals, July 2001 to June 2014

Highlights:

- Postoperative in-hospital mortality rates were generally trending downwards
- Inpatient characteristics explained most of the observed variation in mortality
- No high-mortality hospitals were found across major surgical groups