Hospital-acquired complications: the relative importance of hospital- and patient-related factors

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The known: Hospital-acquired complications are frequent events, and variation in rates between hospitals is often interpreted as indicating differences in quality of health care, despite the complex interactions between hospital- and patient-related factors.

The new: During 2015–2018, hospital-acquired complications were reported for 9.7% of major hospital episodes in South Australia and Victoria. Patient characteristics on admission were the major determinant, explaining 55% of overall variance in rates, compared with 5% for hospital characteristics.

The implications: Hospital-acquired complication rates reflect casemix and patient characteristics more than hospital factors and quality of care. Clinical validation of our findings and revision of our interpretation of complications are warranted.

Abstract

Objective: To quantify the prevalence of hospital-acquired complications; to determine the relative influence of patient- and hospital-related factors on complication rates.

Design, participants: Retrospective analysis of administrative data (Integrated South Australian Activity Collection; Victorian Admitted Episodes Dataset) for multiple-day acute care episodes for adults in public hospitals.

Setting: Thirty-eight major public hospitals in South Australia and Victoria, 2015–2018.

Main outcome measures: Hospital-acquired complication rates, overall and by complication class, by hospital and hospital type (tertiary referral, major metropolitan service, major regional service); variance in rates (intra-class correlation coefficient, ICC) at the patient, hospital, and hospital type levels as surrogate measures of their influence on rates.

Results: Of 1 558 978 public hospital episodes (10 029 918 bed-days), 151 486 included a total of 214 286 hospital-acquired complications (9.72 [95% CI, 9.67–9.77] events per 100 episodes; 2.14 [95% CI, 2.13–2.15] events per 100 bed-days). Complication rates were highest in tertiary referral hospitals (12.7 [95% CI, 12.6–12.8] events per 100 episodes) and for episodes including intensive care components (37.1 [95% CI, 36.7–37.4] events per 100 episodes). For all complication classes, inter-hospital variation was determined more by patient factors (overall ICC, 0.55; 95% CI, 0.53–0.57) than by hospital factors (ICC, 0.04; 95% CI, 0.02–0.07) or hospital type (ICC, 0.01; 95% CI, 0.001–0.03).

Conclusions: Hospital-acquired complications were recorded for 9.7% of hospital episodes, but patient-related factors played a greater role in determining their prevalence than the treating hospital.

Every health care intervention entails risks of preventable human and system errors, and every disease includes risks of serious complications, some avertible. In both cases, serious adverse events during hospital care can ensue, increasing morbidity, delaying recovery, and increasing costs (Box 1). Examples of complications related to health care error include anaphylaxis following administration of a known allergen, venous thrombo-embolism because prophylaxis was neglected, and bowel perforation during diagnostic endoscopy. Complications related to patient factors include anaphylaxis elicited by a previously unrecognised allergen, thrombo-embolism despite optimal prophylaxis, and spontaneous bowel perforation caused by occult cancer.

To improve "safety and quality in the provision of health care services",[1] the Australian Commission on Safety and Quality in Health Care (ACSQHC), in collaboration with Australian health policy institutes,[2,3] developed their hospital-acquired complication classification system, now endorsed by all Australian health departments. The ACSQHC system focuses on 41 serious adverse clinical events grouped into 16 classes "for which clinical risk mitigation strategies may reduce the risk of that complication occurring".[4] Health services are encouraged to evaluate hospital-acquired complications, identify gaps in health care, and implement risk mitigation measures.[4]

Complications related to patient or hospital factors have similar consequences for morbidity, hospital stay, and costs[5] (Box 1), but distinguishing between the two types is essential for clinical interpretation and risk mitigation.

The influence of patient factors (age, diagnosis, comorbidity) and hospital factors (site, type, standard of care) on hospital-acquired complication rates has not been examined in Australia. We therefore analysed administrative data from two Australian states (South Australia, Victoria) to quantify the prevalence and to determine the influence of these factors on hospital-acquired complication rates.

Methods

We extracted data for acute care episodes in public hospitals for the period 1 January 2015 – 31 December 2018 from the Integrated South Australian Activity Collection[6] and the Victorian Admitted Episodes Dataset.[7] Each dataset includes demographic, diagnostic, and clinical information abstracted from medical records by health information managers.

A maximum of forty diagnosis codes (International Classification of Diseases, tenth revision, Australian modification [ICD-10-AM]) are recorded for each hospital episode. The condition onset flag assigned to each diagnosis distinguishes on-admission diagnoses from post-admission complications.[8,9] From each record we extracted diagnosis codes, demographic data (age, sex, clinical urgency, year of separation), and source of admission (home, hospital transfer, aged care facility). We applied published algorithms, modified for the ICD-10-AM, to identify chronic disease[10] and clinical frailty status.[11]

Hospital-acquired complications were identified in post-admission diagnoses data and classified with the national

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1 Categorisation of hospital-associated complications

	Dominant aetiology of hospital-acquired complication	
	Hospital factors	Patient factors
Description	Complication linked to suboptimal care	Complication of disease or treatment despite optimal care
Effect on length of hospital stay	↑	↑
Effect on mortality risk	↑	↑
Effect on health care costs	↑	↑
Predictable on admission	No	Yes
Influenced by standard care	Yes	No
Indicator	Safety and quality of care	Complexity of patient needs
Method of identification	Clinical audit, adverse and sentinel events	Clinical audit, ACSQHC hospital-acquired complication classification system
Interventions to reduce rate	Training, education, health care resources	Informed consent, patient selection, clinical research

ACSQHC = Australian Commission for Safety and Quality in Health Care. ◆

hospital-acquired complications algorithm, version 3.[12] Information about complication onset time was not available, precluding causal inferences. Patient outcomes examined were survival and length of stay.

Hospital factors recorded for each complication included treating site, type of hospital (tertiary referral, major metropolitan, major regional), which differ in their referral patterns, clinical services, and resources;[13] and state, which differ in governance, funding, and population. We also undertook a subgroup analysis of episodes that included treatment in an intensive care unit (ICU).

We included data for multiple-day acute care episodes for adults (18 years or older) in all major public hospitals, defined as those with on-site ICUs. We excluded day-care procedures, non-acute (palliative, rehabilitative) care, and hospital episodes for which the length of stay exceeded 200 days. The dataset precluded three classes of hospital-acquired complications from being included in the primary analysis: 5. unplanned ICU admission (not defined in the national algorithm), 15. perineal tear during delivery (fifteen hospitals did not have obstetric services), and 16. neonatal birth trauma (age exclusion).

Statistical analysis

Analyses were performed in Stata/MP 16.1. Group data are summarised as means with standard deviations (SDs) or medians with interquartile ranges (IQRs). Event rates (with 95% confidence intervals, CIs) were calculated from episode numbers and length of stay data. Between-group differences are reported as standardised mean differences (SMDs); inter-hospital variation in rates was quantified as the coefficient of variation (CV).

The influence of patient and hospital factors on hospital complication rates was estimated in two stages. First, explanatory models were fitted to data for each complication class (binary dependent outcome) with probit regression estimators, and covariates selected from patient factors recorded on admission (demographic characteristics, diagnoses, comorbid conditions), with errors adjusted for clustering within hospitals. Calendar year was included as a fixed covariate to adjust for temporal changes in reporting. The final explanatory model was selected on the basis of the Akaike (AIC) and Bayesian information criteria (BIC),[14] estimated with the Stata *fitstat* command.[15] Propensity scores for the predicted risk (at the time of admission) of a subsequent hospital-acquired complication were estimated for each episode.

Second, a four-level random intercept (probit) regression model was fitted to data for each complication class using the Stata *meprobit* command, with patients (propensity scores) nested in hospitals nested in peer groups as random intercepts. The form of the estimator was:

meprobit [*HAC*] c.*Year* || [*Peer*]: || [*Hospital*]: || [*Patient*]:, *cov*(independent)

where *HAC* = hospital-acquired complication class; *Year* = year of separation; *Peer* = hospital peer group and jurisdiction; *Hospital* = treating hospital; *Patient* = on-admission propensity score; *cov* = variance–covariance structure of the random effects; and || = random intercept logical operator.

This model estimates variance (reported as the intra-class correlation coefficient,[16] ICC) at the patient, hospital, and peer group levels, and thereby the influence of each level on the likelihood of complications. The maximum ICC value of 1.0 indicates substantial influence, an ICC of zero indicates no influence on the likelihood of complications. To test the sensitivity of ICC to identify clinically significant hospital variance, we also estimated the ICC for class 15 (perineal tear during delivery) for the 23 hospitals with and the 15 hospitals without obstetric services. ICC values are probability estimates and not additive.

We selected a low clinical significance limit for SMDs, CVs, and ICCs (0.20) to reduce the risk of type II errors (missing clinically important variation). As the admission diagnosis is itself subject to clinician error, increasing the likelihood of later complications, sensitivity analyses of hospital variance were undertaken in which we excluded admission diagnoses and all patient factors.

Ethics approval

The Eastern Health Human Research Ethics Committee (LNR2020-199585) approved the study. The South Australian Ministry of Health and the Victorian Agency for Health Information provided the datasets, and each approved publication of this article. Hospital identity was removed prior to analysis, and the requirement for patient consent was waived.

Results

We analysed data for 1 558 978 public hospital episodes (10 029 918 bed-days) in 38 major public hospitals with on-site ICUs (Supporting Information, table 1): 369 725 episodes in 12 South Australian hospitals, and 1 189 253 episodes in 26 Victorian hospitals (Box 2). In total, 151 486 episodes (9.72%; 95% CI, 9.67–9.77%) included diagnosis codes for 214 286 hospital-acquired complication events (2.14 [95% CI, 2.13–2.15] events per 100 bed-days) (Box 3).

All 38 hospitals reported complications; rates ranged from 3.22 to 16.5 events per 100 episodes (CV, 0.59) and from 0.31 to 3.17 events per 100 bed-days (CV, 0.92) (data not shown). The most frequent complications were hospital-associated infections (3.64 [95% CI, 3.61–3.67] events per 100 episodes) and renal failure (2.13 [95% CI, 2.11–2.15] events per 100 episodes) (Box 3). Multiple complications were recorded for 43 050 hospital episodes (2.8%; mean, 1.4 [SD, 0.9] complications per episode).

The median age of patients with complications (72 [IQR, 59–82] years) was higher than for those without complications (62 [IQR, 39–77] years), and larger proportions of patients who experienced complications were frail (40% *v* 1%) or had other clinical diagnoses (83% *v* 4%). Further, their median hospital stay was longer (10 [IQR, 6–18] days *v* 4 [IQR, 2–6] days), and a larger proportion died during their hospital stay than for patients without reported complications (8.1% *v* 1.4%) (Box 4).

The combined complication rate was higher for the nine tertiary referral hospitals (12.7 [95% CI, 12.6–12.8] events per 100 episodes) than for the fifteen major metropolitan (7.3 [95% CI, 7.2–7.4] events per 100 episodes) and the twelve regional hospitals (7.9 [95% CI, 7.8–8.0] events per 100 episodes) (Supporting Information, table 2).

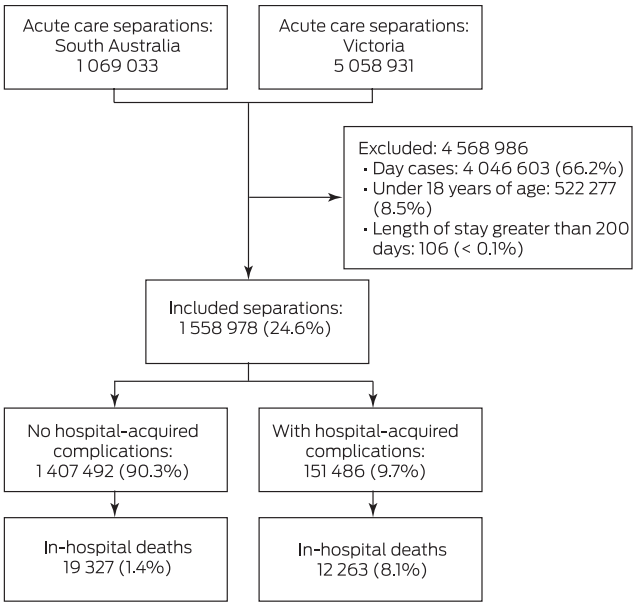
A total of 84 279 events (39.3% of all complications) were recorded for the 126 277 episodes that included treatment in an ICU (8.1% of all separations); the complication rates for these episodes were 37.1 (95% CI, 36.7–37.4) events per 100 separations and 5.24 (95% CI, 5.20–5.27) events per 100 hospital bed-days. We had no information about whether complications arose before, during, or after ICU care.

In our first stage models, a mean of 58 (SD, 22) on-admission patient factors per complication class were significant predictors of later complications (Supporting Information, tables 3 and 4). These models generated a mean of 328 676 (SD, 171 843) distinct (propensity score) subgroups per complication class. In the second stage random effects models, mean variance at the patient level was substantial (ICC, 0.55; 95% CI, 0.53–0.57), while mean variance at the hospital (ICC, 0.04; 95% CI, 0.02–0.07) and peer group levels (ICC, 0.01; 95% CI, 0.001–0.03) was low (Box 5).

In sensitivity analyses, removing admission diagnosis as a factor reduced mean variance at the patient level (mean ICC, 0.33; 95% CI, 0.30–0.37), but removing all patient factors did not affect variance at the hospital level (ICC, 0.05; 95% CI, 0.02–0.09) (Supporting Information, table 5; figures 1–3). In contrast, variance at the hospital level was substantial for class 15 (ICC, 0.58; 95% CI, 0.26–0.86) when the 15 hospitals without obstetric services were included (Box 5).

A small but significant decline in the complication rate between 2015 and 2018 was noted after adjusting for patient admission risk score (by 0.45 [95% CI, 0.42–0.49] events per 100 episodes per year). Rates also declined for nine complication classes (1, 3, 6–8, 10–12, 14), most markedly in class 3, hospital-acquired infections (decline of 0.10 [95% CI, 0.09–0.13] events per 100 episodes per year); rates rose for class 2 (falls resulting in injury: increase of 0.007 [95% CI, 0.004–0.011] events per 100 episodes per year) and class 4 (surgical complications: increase of 0.13 [95% CI, 0.12–0.15] events per 100 episodes per year) (Supporting Information, figure 4 and table 6).

2 Selection of hospital episodes in 38 major hospitals with intensive care units in South Australia and Victoria, 2015–2018



[Correction added on 6 January 2022 after first online publication: Box 2 image has been replaced.]

Discussion

In our analysis of 1.6 million multiple-day adult acute care episodes over 10 million bed-days in 38 major hospitals in South Australia and Victoria, we found that hospital-acquired complications were recorded for 9.7% of hospital episodes; hospital rates ranged from 3.2 to 16.5 events per 100 episodes. Complications were more frequently reported in tertiary referral hospitals than other hospital types, and the rate was greater for episodes including ICU care (37.1 *v* 7.3 events per 100 episodes). Variation in complication rates per bed-day (exposure) were similar.

Complication rates declined for nine of 13 complication classes during 2015–2018. Whether the incidence of complications actually dropped or the declines reflected changes in the documentation and coding of events warrants further investigation. The absence of major rate fluctuations suggests that coding was consistent, despite the ICD-10-AM being revised in 2017.

Patient-related factors influenced the risk of hospital-acquired complications, but the degree of influence differed by complication class (Supporting Information, table 2). The median age of patients who experienced complications was higher than for those who did not, larger proportions were frail or had other clinical conditions, their median hospital stay was longer, and in-hospital mortality was greater for these patients (Box 4).

The importance of patient-related factors for hospital complication rates has been reported in Australia,[3,17] New

3 Numbers and rates (with 95% confidence intervals) of hospital-acquired complication events during 1 558 978 public hospital episodes in 38 major hospitals in South Australia and Victoria, 2015–2018

Class*	Number of episodes†	Number of events‡	Events per 100 episodes	Events per 100 bed-days
1. Severe pressure injury	3360	7015	0.216 (0.208–0.223)	0.034 (0.032–0.035)
2. Fall resulting in injury	1187	1986	0.076 (0.072–0.081)	0.012 (0.011–0.013)
3. Hospital-associated infection	56 788	106 696	3.643 (3.613–3.673)	0.566 (0.562–0.571)
4. Surgical complications	21 854	38 060	1.402 (1.383–1.421)	0.218 (0.215–0.221)
6. Respiratory complications	17 676	37 391	1.134 (1.117–1.151)	0.176 (0.173–0.179)
7. Venous thrombo-embolism	5571	11 560	0.357 (0.348–0.367)	0.056 (0.054–0.057)
8. Renal failure	33 200	35 039	2.130 (2.107–2.153)	0.331 (0.327–0.335)
9. Gastrointestinal bleeding	6706	12 520	0.430 (0.420–0.441)	0.067 (0.065–0.068)
10. Medication complications	5810	10 913	0.373 (0.363–0.382)	0.058 (0.056–0.059)
11. Delirium	28 006	53 357	1.796 (1.775–1.818)	0.279 (0.276–0.283)
12. Persistent incontinence	3640	7021	0.233 (0.226–0.241)	0.036 (0.035–0.037)
13. Malnutrition	15 425	27 793	0.989 (0.974–1.005)	0.154 (0.151–0.156)
14. Cardiac complications	2286	5711	0.147 (0.141–0.153)	0.023 (0.022–0.024)
Total for classes 1–4, 6–14	151 486†	214 286‡	9.717 (9.668–9.766)	2.136 (2.127–2.146)
15. Perineal tear during delivery§	4778	4878	2.964 (2.881–3.050)	0.897 (0.872–0.922)

* Not included: 5. Unplanned intensive care unit admission; 16. Neonatal birth trauma. † Number of hospital episodes coded with this complication class. ‡ Number of complication events from any class coded in this subgroup. § For 23 hospitals with obstetric services and women admitted for childbirth. ◆

Zealand,[18] the United Kingdom,[19] the Netherlands,[20] Canada,[21] and the United States.[22] Our finding that hospital factors had little influence on complication rates was, however, unexpected.[1-4,8] For all complication classes, variation in rates between hospitals and hospital types (Supporting Information, table 4) was chiefly determined by patient-related factors at the time of hospital admission rather than by hospital factors (Box 5).

Similar findings[23,24] have received little attention, despite their clinical implications. First, the influence of patient-related factors should be further examined in a multi-centre clinical audit of reported hospital-acquired complications.[20,25] We support the ACSQHC focus on patient safety and encourage all health services to evaluate local complications data[25] and to develop effective mitigation strategies.

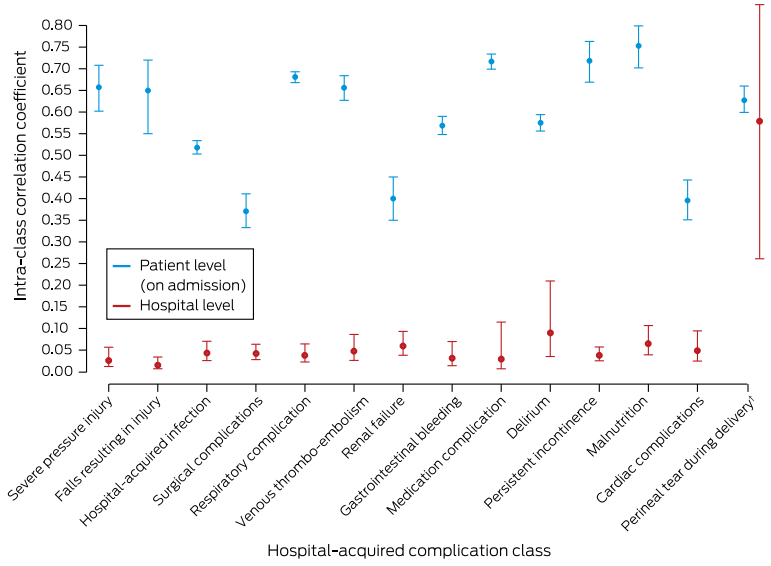
Second, the distinction between antecedent patient and hospital factors is neither a semantic exercise nor a convenient excuse for health services and clinicians. Failure to differentiate between the two groups of factors may lead to practice changes that are clinically sound but ineffective in reducing complication rates. Increasing the funding of health care, improved clinical

4 Patient demographic and admission characteristics, by coding of hospital-associated complication events for admission

Characteristic	Hospital-acquired complications reported	No hospital-acquired complications reported	Standardised mean difference
Episodes	151 486 [9.7%]	1 407 492 [90.3%]	—
Hospital-acquired complication events	214 286	0	—
Patient characteristics			
Age (years), median (IQR)	72 (59–82)	62 (39–77)	0.505
Sex (men)	80 034 (52.8%)	631 392 (44.8%)	0.160
Elective admissions	41 180 (27.2%)	259 703 (18.5%)	0.209
Indigenous Australians	2216 (1.5%)	23 420 (1.7%)	−0.053
In residential care	2108 (1.4%)	11 721 (0.8%)	0.053
Comorbid conditions	125 317 (82.7%)	547 117 (3.9%)	0.500
Frailty	54 468 (40.0%)	174 774 (1.2%)	0.571
Admission characteristics			
Length of stay (days), median (IQR)	10 (6–18)	4 (2–6)	0.789
Intensive care during admission	46 819 (30.9%)	79 458 (5.6%)	−0.692
In-hospital deaths	12 263 (8.1%)	19 327 (1.4%)	0.321

IQR = interquartile range. ◆

5 Conditional intra-class correlation coefficients (with 95% confidence intervals) for patient and hospital levels, by hospital-acquired complication class*



* Hospital peer group ICC values not depicted because of the graph scale; see online Supporting Information, table 5). † Includes 15 hospitals without on-site obstetric services. [Correction added on 6 January 2022 after first online publication: Box 5 image has been replaced.] ◆

guidelines, and training and education may reduce rates of complications attributable to hospital factors and health care errors, but are unlikely to reduce those linked with patient-related factors. These require different solutions, including improved patient selection and risk assessment (using, for example, the Grattan Institute hospital complications calculator: https://grattan.shinyapps.io/all-complications-should-count), more informed discussion of treatment risks and patient consent, and the investigation of therapeutic alternatives with lower risks and fewer side effects.

Third, we recommend that clinicians be engaged in developing clinical indicators, including access to the source data and methodology. Expert interpretation of metadata, selection of appropriate statistical methods, and clinical validation are crucial elements if ineffective or costly approaches are to be avoided.[3]

Fourth, that hospital complication rates are too high is recognised, but it is widely assumed that they are inversely related to the quality of care provided by hospitals.[1-4,23,24,26] Clinical[20,25,27] and epidemiological evidence[23,24] suggests that rates are not necessarily lower in better performing health services. Complications are often anticipated and surveillance instituted, and most are identified and remedied, as required by national standards;[28] all are coded as post-admission diagnoses. Higher rates are therefore expected in better performing health services and in those caring for patients with more complex needs.

Several caveats must, however, be considered. While the definition of "hospital-acquired complication" is agnostic[2-4] and possibly insensitive to health care errors, it does not exclude them.[23,25] Higher complication rates may reflect more complex casemix and high performance, or health care errors and poor performance. Consequently, we should not abandon our national hospital-acquired complications model. The ACSQHC algorithm[12] furnishes a clinical tool for screening, monitoring, and research, while clinical practice guidelines[3] establish minimum clinical standards.

Limitations

We have previously reported that complications are under-reported,[25] but we did not draw on source documents for this analysis. The dataset excluded patients under 18 years of age and admissions to hospitals without ICUs. We did not explore length of stay as an endogenous covariate,[29] which may have increased the numbers of complications in our analyses. An ICC derived from a small number of groups (fewer than six) may underestimate effect size.[16] Our findings may not be generalisable to other health services, or to periods of high demand or limited hospital resources.

Conclusion

Complications were frequent events in all hospitals (9.7% of hospital episodes), and were more frequent in tertiary referral hospitals and during hospital episodes including an intensive care component. We found that complication rates were determined more by patient than hospital factors. This has implications for interpreting hospital-acquired complication reports and mitigating risk. Current approaches to quantifying hospital-acquired complications assess hospital admission complexity rather than quality of care.

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Supporting Information

Additional Supporting Information is included with the online version of this article.