Research

Measuring the incidence of hospital-acquired complications and their effect on length of stay using CHADx

Kevin M Trentino
BCom,
Benchmarking Analyst[1]

Stuart G Swain
BCM,
Manager, Business Systems[1]

Sally A Burrows
BMath, GradDipMedStat,
Statistician[2]

Peter C Sprivulis
MB BS, PhD, FACEM,
Professor of Emergency Medicine[3]

Frank F S Daly
MB BS, FACEM, FLWA,
Executive Director[4]

1 Performance Unit, South Metropolitan Health Service, Perth, WA.

2 School of Medicine and Pharmacology, University of Western Australia, Perth, WA.

3 School of Primary, Aboriginal and Rural Health Care, University of Western Australia, Perth, WA.

4 Royal Perth Group, South Metropolitan Health Service, Perth, WA.

kevin.trentino@health.wa.gov.au

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Abstract

Objectives: To use an automated Classification of Hospital Acquired Diagnoses (CHADx) reporting system to report the incidence of hospital-acquired complications in inpatients and investigate the association between hospital-acquired complications and hospital length of stay (LOS) in multiday-stay patients.

Design: Retrospective cross-sectional study for calendar years 2010 and 2011.

Setting: South Metropolitan Health Service in Western Australia, which consists of two teaching and three non-teaching hospitals.

Main outcome measures: Incidence of hospital-acquired complications and mean LOS for multiday-stay patients.

Results: Of 436 841 inpatient separations, 29172 (6.68%) had at least one hospital-acquired complication code assigned in the administrative data, and there were a total of 56326 complication codes. The three most common complications were postprocedural complications; cardiovascular complications; and labour, delivery and postpartum complications. In the subset of data on multiday-stay patients, crude mean LOS was longer in separations for patients with hospital-acquired complications than in separations for those without such complications (17.4 days v 5.4 days). After adjusting for potential confounders, separations for patients with hospital-acquired complications had almost four times the mean LOS of separations for those without such complications (incident rate ratio, 3.84; 95% CI, 3.73–3.96; $P < 0.001$).

Conclusions: An automated CHADx reporting system can be used to collect data on patients with hospital-acquired complications. Such data can be used to increase emphasis on patient safety and quality of care and identify potential opportunities to reduce LOS.

In July 2008, a condition-onset flag was added to the specifications of the International Statistical Classification of Diseases and Related Health Problems (10th revision, Australian modification) (ICD-10) codes. This created the opportunity to distinguish between hospital-acquired complications and comorbidities present on admission in routinely coded administrative data. To help analyse this flag, the Australian Centre for Economic Research on Health (under sponsorship by the Australian Commission on Safety and Quality in Health Care) developed a classification system known as the Classification of Hospital Acquired Diagnoses (CHADx).[1] This system provides hospitals with a meaningful way of grouping complications that are coded as arising in hospital into 17 classes (eg, adverse drug events and postprocedural complications) and 145 subclasses, and a way of reducing double counting of codes when they are recorded in related sequences.[1,2]

The costs associated with hospital-acquired complications are well documented.[3-6] One Australian study estimated that complications increase treatment costs by 17%.[7] As well as increased costs, overseas studies have shown significantly longer length of stay (LOS) in patients who experience indicator conditions such as adverse drug events,[8] hospital-acquired infections[9] and postoperative complications.[10] However, few studies report effects on LOS for the full range of hospital-acquired complications.

These results suggest that an automated system for reporting hospital-acquired complications would be valuable. Monthly use of CHADx as a tool to monitor trends in hospital-acquired complication rates and patient safety has been suggested.[1] While initial results of analysis of jurisdictional data have been reported,[1,7] we found no examples of CHADx implementation at the hospital level. To our knowledge, no hospitals have implemented local systems to take advantage of this classification and monitoring tool. This may be due to the apparent complexity of the CHADx system.

Here, we report the initial results of implementation of an automated CHADx reporting system in the South Metropolitan Health Service (SMHS) in Western Australia. In the absence of software to group inpatient separation data, we developed an abstract model that assigns combinations of diagnosis codes to CHADx classes and subclasses.[11] We aimed to report the incidence of hospital-acquired complications in all inpatients presenting to the SMHS and investigate the association between hospital-acquired complications and hospital LOS in multiday-stay patients.

Methods

The SMHS is one of four health services in the state of WA. It consists of two teaching hospitals and three non-teaching hospitals that treat more than 35% of WA's population. Over the 2010 and 2011 calendar years, these five sites had an average of 220000 emergency department (ED) presentations and over 215000 inpatients per year.

We obtained data from the SMHS Clinical Activity Data Warehouse (an extensive repository of inpatient, outpatient and ED data that are used for operational and strategic reporting, activity-based funding and management, and analysis purposes). We

1 Characteristics of inpatient separations, South Metropolitan Health Service, 2010–2011*

Characteristic	Male (*n* = 229 011)	Female (*n* = 207 830)	Total (*n* = 436 841)
Mean (SD) patient age, years	54.3 (22.5)	53.3 (23.6)	53.8 (23.0)
Aboriginal or Torres Strait Islander	15 349 (6.70%)	18 289 (8.80%)	33 638 (7.70%)
Diagnosis-related group category			
Medical	169 224 (73.89%)	155 970 (75.05%)	325 194 (74.44%)
Surgical	41 528 (18.13%)	35 956 (17.30%)	77 484 (17.74%)
Other	18 259 (7.97%)	15 904 (7.65%)	34 163 (7.82%)
Acute care	215 258 (93.99%)	189 923 (91.38%)	405 181 (92.75%)
Non-overnight admission	130 210 (56.86%)	106 466 (51.23%)	236 676 (54.18%)
Separation type			
Deceased	1 942 (0.85%)	1 540 (0.74%)	3 482 (0.80%)
Statistical	4 325 (1.89%)	5 127 (2.47%)	9 452 (2.16%)
Transfer	29 540 (12.90%)	25 661 (12.35%)	55 201 (12.64%)
Home	193 204 (84.36%)	175 502 (84.44%)	368 706 (84.40%)
Emergency admission	91 185 (39.82%)	84 024 (40.43%)	175 209 (40.11%)
Mean (SD) length of stay, days	3.5 (9.3)	3.4 (8.6)	3.4 (9.0)
Any CHADx code	13 472 (5.88%)	15 700 (7.55%)	29 172 (6.68%)

CHADx = Classification of Hospital Acquired Diagnoses. * Data are number (%) unless otherwise stated. ◆

2 CHADx subclasses with the 20 largest numbers of CHADx codes

Subclass	Description	No. (%) of CHADx codes (*n* = 56 326)
5.06	Hypotension	2 773 (4.92%)
15.02	Electrolyte disorders without dehydration	1 992 (3.54%)
5.03	Cardiac arrhythmias, conduction disturbances and abnormal heart beat	1 927 (3.42%)
9.02	Urinary tract infections	1 548 (2.75%)
10.04	Alterations to mental state	1 221 (2.17%)
15.01	Dehydration / volume depletion	1 154 (2.05%)
12.07	Second degree perineal laceration	1 153 (2.05%)
2.16	Adverse effects due to other drugs	1 133 (2.01%)
7.01	Gastroenteritis	1 112 (1.97%)
6.03	Acute lower respiratory infections (including influenza and pneumonia)	1 102 (1.96%)
8.03	Dermatitis, rash and other skin effects	1 094 (1.94%)
1.04	Other haemorrhage and haematoma complicating a procedure (not elsewhere classified)	1 077 (1.91%)
13.11	Other neonatal complications	1 074 (1.91%)
7.04	Constipation	1 058 (1.88%)
17.04	Chest pain	1 029 (1.83%)
17.06	Fever (not classified to condition)	910 (1.62%)
9.01	Acute and unspecified renal failure	898 (1.59%)
3.03	All other falls	863 (1.53%)
14.02	Other hospital-acquired anaemia	859 (1.53%)
7.05	Nausea and vomiting	811 (1.44%)
	All other CHADx subclasses	31 538 (55.99%)

CHADx = Classification of Hospital Acquired Diagnoses. ◆

retrospectively analysed data for the period January 2010 to December 2011 for the five SMHS sites. We extracted data for all inpatient separations, including those for patients whose LOS was 1 day (eg, patients admitted for dialysis).

For patients who were admitted and stayed overnight, LOS was defined as the number of nights that the patient stayed in hospital, excluding any leave days. Patients who were admitted but did not stay overnight were assigned a LOS of 1 day.

We also created a subset of inpatient separation data for multiday-stay patients. To do so, we excluded patients who were admitted and discharged on the same day, patients who presented to the ED with chest pain and stayed past midnight (because this large group of multiday-stay patients predominantly had a short stay), and patients admitted for obstetric or neonatal care. Patients admitted for obstetric or neonatal care were excluded from the LOS analysis as they differed from other multiday-stay patients. For example, unlike other hospital patients, generally speaking, this group are in good health and are not presenting for a "pathological condition". Also, as described by the CHADx authors, the complications arising from this group of patients are handled differently in the classification system.[12] These important differences affect the exposure of interest (ie, risk of experiencing a hospital-acquired complication) and the main outcome measure (ie, hospital LOS).

The study was registered with the relevant hospital clinical governance units and approved by the SMHS Human Research Ethics Committees.

Variables

Potential confounders (eg, patient age, hospital, Indigenous status, diagnosis-related group (DRG) category, separation type, admission type and sex) were included in the analysis. Separation types were grouped into four categories: deceased, statistical, transfer and home. Statistical separation occurs when a patient's care type (ie, nature of the clinical service provided) changes during their hospital stay (eg, from acute care to rehabilitation care). During this administrative process, the patient is discharged from the patient administration system and readmitted, resulting in two episodes of care.

It was difficult to find a suitable measure that could be used to adjust for patient complexity. All available measures were based on the coded diagnoses — comorbidities present on admission and complications arising in hospital. We reviewed the ICD-10 Deyo version of the Charlson comorbidity index (CCI)[13] and found that 7% of diagnoses making up the CCI score were not present on admission (ie, they were hospital acquired). To account for this we removed hospital-acquired complications from the CCI score, and therefore refer to this measure as the adjusted CCI.

Statistical analysis

Numbers and rates of separations with at least one CHADx code assigned were analysed. Also analysed were the sum of hospital-acquired complications in each of the CHADx classes and subclasses. Unadjusted results comparing separations for patients with and without hospital-acquired complications were analysed using the χ^2 test for categorical variables and the independent samples *t* test for continuous variables.

Regression methods for count outcomes are commonly Poisson based and require equal mean and variance to avoid biased estimates. When the variance is larger than the mean, the data are said to exhibit overdispersion. Negative binomial regression is an extension of Poisson regression that includes an additional parameter to account for overdispersion. Truncated count distributions in which a zero count is not possible require modification of the negative binomial or Poisson distribution to exclude the probability of a zero observation. In our study, LOS could not be zero and the distribution of LOS was overdispersed, so we used zero truncated negative binomial regression to model our data for our analysis of the impact of hospital-acquired complications and other variables on LOS.

Results of our analysis on LOS are expressed as incident rate ratios (IRRs) with 95% confidence intervals. The IRRs indicate the rate of increase or decrease in LOS for one group when compared with the reference group for categorical covariates or for an increase of 1 unit in continuous covariates. A robust variance adjustment was applied in our regression model to account for correlation between multiple admissions for the same patient.

Analyses were performed using Stata version 12 (StataCorp) and IBM SPSS Statistics, version 20 (SPSS Inc). *P* values are two sided with significance set at the 5% level.

Results

For the 2-year study period, our dataset contained 436 841 inpatient separations (Box 1). Patients had a mean age of 53.8 years (SD, 23.0 years) and 229 011 (52.42%) were male. Based on the CHADx mapping rules of our model, 29 172 of the separations (6.68%) had at least one hospital-acquired complication code assigned; these 29 172 separations had a total of 56 326 CHADx codes assigned (ie, a mean of 1.93 CHADx codes per separation). The median adjusted CCI was 0 (range, 12).

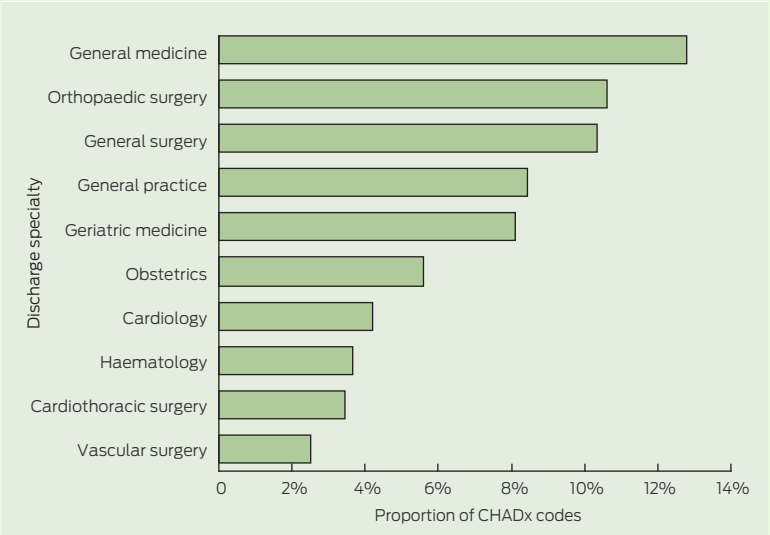
Incidence of hospital-acquired complications

The three most frequently occurring hospital-acquired complications as described by the CHADx classes were postprocedural complications; cardiovascular complications; and labour, delivery and postpartum complications. These accounted for 33.35% (18 785) of CHADx codes. The five most frequently occurring subclasses were: hypotension; electrolyte disorders without dehydration; cardiac arrhythmias, conduction disturbances and abnormal heart beat; urinary tract infections; and alterations to mental state (Box 2). These made up 16.80% (9461) of CHADx codes. The 20 most frequently occurring CHADx subclasses accounted for 44.01% (24 788) of CHADx codes.

General medicine was the specialty with the most hospital-acquired complications. Orthopaedic surgery, general surgery, cardiothoracic surgery and vascular surgery were among the top 10 specialties (Box 3). These 10 specialties reported 69.69% (39 253) of CHADx codes.

The DRGs with the 10 largest numbers of CHADx codes represented fewer than 2.60% of all DRGs (our sample consisted of 385 different DRGs) but accounted for 38.62%

3 Discharge specialties with the 10 largest numbers of CHADx codes



CHADx = Classification of Hospital Acquired Diagnoses. ◆

4 DRGs with the 10 largest numbers of CHADx codes

DRG family	Description	No. (%) of CHADx codes (*n* = 56 326)
Z60	Rehabilitation	4 146 (7.36%)
O60	Vaginal delivery	3 944 (7.00%)
A06	Tracheostomy and/or ventilation > 95 hours	3 598 (6.39%)
P67	Neonate, admit weight > 2499 g without significant operating room procedure	3 030 (5.38%)
O01	Caesarean delivery	1 439 (2.55%)
I03	Hip replacement	1 403 (2.49%)
I08	Other hip and femur procedures	1 346 (2.39%)
G02	Major small and large bowel procedures	1 207 (2.14%)
E62	Respiratory infections/inflammations	884 (1.57%)
I04	Knee replacement	754 (1.34%)
	All other DRGs	34 575 (61.38%)

DRG = Diagnosis-related group. CHADx = Classification of Hospital Acquired Diagnoses. ◆

(21 751) of CHADx codes (Box 4). The rehabilitation DRG had the largest number of CHADx codes, with 7.36% of the total.

Hospital-acquired complications and multiday length of stay

Our subset of data on multiday-stay patients contained 172 827 separations. This total excluded 8435 separations for patients who presented to the ED with chest pain (for whom median LOS was 9 hours). Multiday-stay patients had a mean age of 54.8 years (SD, 23.9 years); 91 132 (52.73%) of the separations for multiday-stay patients involved male patients, 10 199 (5.90%) involved Aboriginal or Torres Strait Islander patients, and there were 122 950 (71.14%) emergency admissions. The mean LOS for multiday-stay patients was 6.9 days (SD, 13.5 days).

According to unadjusted rates of complications in separations for multiday-stay patients, the group with hospital-acquired complications had a higher mean age (65.4 years v 53.3 years), lower proportion of emergency admissions (64.17% v 72.16%), lower proportion of patients discharged home (58.37% v 83.01%) and higher proportion of surgical patients (43.63% v 25.87%) than the group with no hospital-acquired complications (Box 5).

Crude mean LOS was longer in the group with hospital-acquired complications than the group without (17.4 days v 5.4 days) (Box 5). An unadjusted IRR of 4.91 (95% CI, 4.77–5.06) indicated an almost fivefold increase in LOS for the group with complications. After adjusting for age, hospital, Indigenous status, DRG category, separation type, admission type, sex and adjusted CCI score, there was an almost fourfold increase (IRR, 3.84; 95% CI, 3.73–3.96) (Box 6).

5 Characteristics of inpatient separations for multiday-stay patients with and without hospital-acquired complications*

Characteristic	Hospital-acquired complication		*P*
	Yes (*n* = 22 005)	No (*n* = 150 822)	
Mean (SD) length of stay, days	17.4 (24.2)	5.4 (10.2)	< 0.001
Mean (SD) patient age, years	65.4 (19.7)	53.3 (24.0)	< 0.001
Male	11 534 (52.42%)	79 598 (52.78%)	0.32
Aboriginal or Torres Strait Islander	1 048 (4.76%)	9 151 (6.07%)	< 0.001
Emergency admission	14 121 (64.17%)	108 829 (72.16%)	< 0.001
Acute care	19 118 (86.88%)	134 133 (88.93%)	< 0.001
Separation type			< 0.001
Deceased	1 276 (5.80%)	1 879 (1.25%)	
Statistical	2 176 (9.89%)	6 671 (4.42%)	
Transfer	5 708 (25.94%)	17 070 (11.32%)	
Home	12 845 (58.37%)	125 202 (83.01%)	
Diagnosis-related group category			< 0.001
Medical	11 326 (51.47%)	105 578 (70.00%)	
Other†	1 079 (4.90%)	6 223 (4.13%)	
Surgical	9 600 (43.63%)	39 021 (25.87%)	

* Data are number (%) unless otherwise stated. † Separations assigned a "non-operating room" procedure according to the diagnosis-related group grouper software (eg, endoscopic procedures). ◆

6 Impact of hospital-acquired complications and other variables on length of stay for multiday-stay patients, according to multivariable regression analysis*

	Incident rate ratio (95% CI)	*P*
Any CHADx code	3.84 (3.73–3.96)	< 0.001
Age	1.01 (1.01–1.01)	< 0.001
Hospital		
A	0.74 (0.70–0.78)	< 0.001
B	2.57 (2.36–2.80)	< 0.001
C	1.05 (1.02–1.08)	0.002
D	0.63 (0.59–0.66)	< 0.001
E	Reference	–
Aboriginal or Torres Strait Islander	1.05 (1.00–1.11)	0.07
Diagnosis-related group category		
Surgical	0.97 (0.94–0.99)	0.02
Other†	0.90 (0.86–0.93)	< 0.001
Medical	Reference	–
Separation type		
Deceased	0.94 (0.88–1.01)	0.11
Statistical	1.89 (1.80–1.98)	< 0.001
Transfer	1.55 (1.50–1.60)	< 0.001
Home	Reference	–
Emergency admission	1.21 (1.17–1.25)	< 0.001
Male	1.14 (1.11–1.17)	< 0.001
Acute care	0.36 (0.35–0.38)	< 0.001
Adjusted Charlson comorbidity index	1.19 (1.18–1.20)	< 0.001

CHADx = Classification of Hospital Acquired Diagnoses. * Zero truncated negative binomial regression was used to model the data. † Separations assigned a "non-operating room" procedure according to the diagnosis-related group grouper software (eg, endoscopic procedures). ◆

Discussion

In our five-hospital sample, multiday-stay patients who experienced hospital-acquired complications stayed in hospital on average almost four times longer than patients without such complications, even after taking into account a range of factors that might also explain increased LOS.

Our findings of increased LOS are consistent with data from other studies.[3,14-16] An observational study that used multivariable matching to measure excess LOS, cost and mortality attributable to hospital-acquired complications highlighted the significant impact that complications have on LOS — up to 10 extra days were attributed to complications such as postoperative sepsis, selected infections due to medical care and postoperative wound dehiscence.[16]

LOS is used to assess quality of patient care and hospital costs, and is the central measure underpinning the national activity-based funding model.

Routine internal reporting of hospital-acquired complications using the CHADx system assists our health service in identifying potential opportunities to reduce LOS, and thus costs. The difference between the crude and adjusted LOS highlights the influence of casemix and severity and hence the importance of adjusting estimates for these factors. The hospital variation, evidenced in the regression of LOS data, illustrates the advantage of enabling each hospital to access its own complication data.

In addition to estimating the relationship between complications and LOS, implementing the CHADx system has allowed us to report on the incidence and frequency of hospital-acquired complications on an ongoing basis. To aid analysis, we include CHADx in our hospital business intelligence tools. These tools are refreshed daily and allow users to analyse CHADx rates by specialty, DRG, ward and other clinically meaningful factors. These tools have been useful for identifying the potential benefits of hospital-wide patient safety initiatives such as the WA Patient Blood Management Program.[17]

The ability to report patterns and trends of hospital-acquired complications is valuable for many reasons. Although not the sole element, a key part in consistently improving patient safety and quality of care is the feedback of meaningful data to clinicians and other decisionmakers.[18] Also, hospital-acquired complications play a role in funding in some countries. The Medicare system in the United States excludes funding for specific hospital-acquired complications in an attempt to remove incentives for substandard care.[19] It is possible that future payment models in Australia may include similar incentives, given that the Independent Hospital Pricing Authority has evaluated the US Medicare approach.[20]

Our automated system identified the most common classes and subclasses of complications and the clinical areas and patient groups associated with these. Patients undergoing rehabilitation had the largest number of hospital-acquired complications. Likely contributing factors are higher average age and longer LOS. Our results also highlight that a small number of patient groups account for a large proportion of hospital-acquired complications — 20 CHADx subclasses accounted for nearly half of such complications.

These insights could be used to identify combinations of complications and types of procedures or patients for which a review of standard practice may be warranted. For example, hospital-acquired anaemia was among the most common complications and patients who had knee replacements were one of the higher-risk groups in terms of complications. Such findings provide direction for future research on preventing complications.[21]

This study has some limitations. First, it is a retrospective cross-sectional study, so the findings show only an association between complications and differences in LOS. Longer stays may expose patients to more hazards, but longer stays may have been generated by hazards or complications experienced earlier during admission. We did, however, statistically control for possible effects of other causative factors.

Second, for complications to be identified, two important steps are required: good clinical documentation in the patient notes and translation of the notes into ICD-10 codes by professional coders. For this reason, the coded data are likely to underrepresent the number of hospital-acquired complications.[22] This underestimation, however, is difficult to measure. One of the reasons for this is that the CHADx system was designed to monitor the full range of hospital-acquired complications[1] and its level of accuracy is likely to vary between groups of complications. For example, it has been shown that coded data are a poor indicator of hospital-acquired infections[23] and that coded data are more reliable for surgical patients than medical patients.[24] In addition, classification systems based on coded data are influenced by variations in the accuracy and completeness of clinical documentation and coding between hospitals and jurisdictions.[12]

Even with these limitations, we have found that reporting hospital-acquired complications using the CHADx system is valuable in understanding and describing the incidence and effects of such complications in our hospitals. Studying the patterns of these outcomes may help clinicians provide more expert care and help hospital administrators to target resources to areas where care could be improved.

Competing interests: No relevant disclosures.

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