Marginal costs of hospital-acquired conditions: information for priority-setting for patient safety programmes and research

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Abstract

Objective: To use cost data to estimate relative inpatient costs of hospital-acquired diagnoses.

Methods: Patient level costs are estimated using computerised costing systems that log individual utilization of inpatient services, and apply sophisticated cost estimates from the hospital's general ledger. Occurrence of a hospital-acquired diagnosis is identified using an Australian 'condition-onset' flag for diagnoses not present on admission. These are grouped to yield a comprehensive set of 144 categories of hospital-acquired conditions to summarise data coded with ICD-10. Standard linear regression techniques are used to identify the independent contribution of hospital-acquired conditions to costs, taking into account the casemix of a sample of acute inpatients (n= 1,699,997) treated in Australian public hospitals in Victoria (2005/06) and Queensland (2006/07).

Results: The most costly types of complications were post-procedure endocrine/metabolic disorders, adding ($A) 21,869 to the cost of an episode, followed by MRSA (19,892) and enterocolitis due to *Clostridium difficile* (19,745). Aggregate costs to the system, however, were highest for septicaemia (41.5 mil), complications of cardiac and vascular implants other than septicaemia (28.7 mil), acute lower respiratory infections, including influenza and pneumonia (28.0 mil) and UTI (24.7 mil). Hospital acquired complications are estimated to add 17.1 % to treatment costs in this sample.

Conclusions: Patient safety efforts frequently focus on dramatic but rare complications with very serious patient harm. Previous studies of the costs of adverse events have provided information on 'indicators' of safety problems rather than the full range of hospital acquired conditions. Adding a cost dimension to priority-setting could result in changes to the focus of patient safety programs and research. Financial information should be combined with information on patient outcomes to allow for cost-utility evaluation of future interventions.

Introduction

Priority-setting for patient safety programmes needs to take multiple factors into account: the frequency of the events leading to patient harm, the severity of outcomes, the absolute numbers of patients harmed, the evidence-base for the success of preventive efforts, the feasibility and acceptability of such interventions, and of course, the economic losses due to these events. One large contributor to economic loss is the additional costs of hospital care attributable to adverse events, over and above the costs of treating the patient's diagnoses on admission.[1]

Most efforts to use hospital administrative data to characterise patient complications have been premised on public reporting. This expectation has led to considerable investment in risk-adjustment approaches[2-4] and to focussing research effort on complications deemed to be preventable.[5] Using these tools, which focus on predetermined conditions of interest, it is not possible to estimate the relative contribution of *all* hospital-acquired illness and injury. Yet, estimation of 'preventability' changes, as new scientific evidence of causal factors emerges, together with new research on effective prevention.

Zhan and Miller's landmark 2003 study estimated additional costs of 18 types of 'medical injury'. More recently, Shreve et al. have published estimates of the costs of 50 classes of 'medical error', building on Layde et al.'s earlier classification of inpatient events. These US studies rely on billed charges to quantify costs, and did not have access to timing information to distinguish pre-hospitalisation from inpatient events, relying instead on sets of 'external cause of injury codes' to identify adverse outcomes.

Two Australian studies have attempted to quantify the costs of hospital-acquired conditions. The first[6] applied DRG cost-weights to a sample of patient records from the Quality in Australian Health Care study[7] to estimate the costs of adverse events. The second, and more recent study,[8] used costing data from a single Australian state public hospital system to estimate the additional costs of adverse events.

The weaknesses of this study in setting priorities for prevention programmes, however, are that it resorted to *ad hoc* groupings of hospital-acquired diagnosis codes, considered only the first-recorded diagnosis of an in-hospital complication, and used cost data from only one State (Victoria). The recently reported Classification of Hospital Acquired Diagnoses (CHADx)[9] allows us to characterise complications of hospital care in a systematic and reproducible way. This categorisation contains 17 Major CHADx classes, and 144 more detailed and comprehensive subclasses, using a condition onset flag to distinguish comorbidities from conditions arising in hospital. In this paper we describe

the use of the CHADx to estimate the per-case and total financial burdens of inpatient complications to the public hospital systems of two Australian states, representing nearly 40% of the Australian population.

Methods

Design: We use secondary analysis of routine hospital data on patient-level diagnoses, procedures and costs.

Sample: Table 1 describes the de-identified patient-level data on the 1.7 million costed public hospital episodes analysed.

Table 1: Description of data sets

	Victoria	Queensland	Total
Financial year data collection	2005/06	2006/07	
N of hospitals	45	23	68
N of episodes analysed	1,083,844	616,153	1,699,997
% of sample	64%	36%	100.00
Total recorded costs	$A3,454 mil	$A1,899 mil	$A5,353 mil
Mean cost per case	$A3,187	$A3,082	$A3,149
Mean length of stay (days)	2.95	2.99	2.97
% Same-day admissions	69.98	65.11	68.22
Diagnosis fields available	40	50	50
Mean coding depth	3.43	3.79	3.56
Incidence of any CHADx	126,656 (11.68%)	82,122 (13.32%)	208,778 (12.28%)
Mean of CHADx per record*	0.23	0.19	0.22
Mean of CHADx in records with any recorded complication	2.03	1.89	1.99

* The mean of CHADx per record is calculated as the ratio of number of CHADx to the number of episodes. Since there are many episodes in which a patient suffered more than one CHADx (see average CHADx per complication episode in the next line), the mean of CHADx per record is larger than the incidence of CHADx.

Research Variables:

Diagnosis Codes:

Diagnosis data are abstracted from patient records by trained professional coders or health information managers; we truncated the records at 50 diagnosis fields. In both states, data are routinely edited by the respective health departments against published standards for plausible code combinations, and both states conduct audits of patient records from public hospitals.[10,11] In Victoria, financial penalties are applied for funded

hospitals with exceptional rates of coding error.[11] National coding standards require that all diagnoses monitored or treated during the admission be recorded.[12]

Diagnosis Onset Flag:

Victorian coding has included information on the timing of diagnoses since at least 1980. For application of a 'C' prefix (indicating a 'complication') the coder must ascertain that there was no evidence of the condition existing prior to admission, that is, the C-prefix is used only for a diagnosis arising after admission. Queensland adopted a similar numeric 'diagnosis onset flag' in July 2006. Both distinguish co-morbidities from hospital-acquired diagnoses, and incident diagnoses (arising during the current episode) from those in readmission episodes.[13] The more recent adoption of onset-flagging by Queensland meant that only one year (2006/07) of data was available. Flagging was evaluated using a recently developed algorithm to identify chronic and congenital conditions that are unlikely to be hospital-acquired.[14]

Total Cost:

State health authorities in both Victoria and Queensland collect annual patient-level costing datasets from public hospitals in their respective states. Costs are estimated using computerised clinical costing systems that identify the costs of hospital care for individual patients.[15] The 45 hospitals contributing to the dataset from Victoria are larger urban hospitals, accounting for 86.4% of weighted inpatient activity (i.e., weighted according to complexity) for the period 1 July 2005–30 June 2006. These costs are subjected to data quality checks before calculation of cost weights for casemix-based hospital funding, including re-submission of cases with missing data to the originating hospital.[15]

A later dataset was requested from Queensland Health because it was the second state in Australia to flag hospital-acquired diagnoses, beginning only in the 2006/2007 FY. The Queensland cost data are collected from all hospitals in the state for submission to the National Hospital Cost Data Collection (NHCDC). In this study, we use only those costed episodes evaluated and accepted for inclusion in the National dataset (n= 616,153 cases in 23 hospitals).

Cost per case includes the costs of treating the primary diagnosis (reason for admission), any additional costs attributable to 'present on admission' diagnoses (co-morbidities), and the costs of any hospital-acquired diagnoses (complications).

Uncomplicated Treatment Cost: that portion of each patient's measured cost per case attributable to their principal diagnosis and co-morbidities. This is calculated for each DRG as the mean of all episodes with no Hospital Acquired Diagnosis (CHADx).

Mean Corrected Treatment Cost: that portion of each patient's measured cost per case remaining after subtracting the Uncomplicated Treatment Cost for the DRG assigned to the episode. These costs are used as the dependent variable in linear regression analyses to estimate the marginal effects of each CHADx.

Total Cost: a calculation of the costs attributable to a particular CHADx based on the marginal CHADx Treatment Cost multiplied by the number of instances of the CHADx in the study database.

Sameday patients: a dummy variable, equal to one for patients treated in hospital on a 'sameday' basis, and zero for multi-day patients. The Australian DRG version, AR-DRGs,[16] incorporates all inpatient episodes, including sameday surgery and other procedures classed as 'ambulatory' in other classification systems.

Death in Hospital: a dummy variable equal to one if the patient dies in hospital, and zero otherwise, to control for any costs associated with end-of-life treatment that might distort estimates of costs for some hospital-acquired conditions.

Analysis

Standard linear regression was used to investigate the relationship between the cost of hospitalisation and adverse events, after controlling for other covariates. Specification tests were applied to verify the choice of variables, and a heteroskedasticity test was applied to test the assumption of constant variance in regression analyses.

Since our data represent a relatively large sample (1.7 million observations), standard regressions can be used to produce robust and consistent results in spite of the fact that the cost data may not satisfy the normality assumption.[17] Untransformed data allow the expression of results in easily-interpretable dollar terms.

Results

Table 2 shows the full results from our OLS model. As expected, the majority of CHADx dummy variables have positive and significant parameter estimates, suggesting that they consistently add cost compared with uncomplicated episodes in the same DRG. The costs of same-day episodes and those episodes where the patient dies in hospitals are significantly lower compared with other episodes. Our model achieved an R^2 of 0.26.

Table 2: Complete OLS estimates for costs not attributable to treatment of an uncomplicated case in the same DRG.

Intercept			
Died in hospital			-$ 1,139
Sameday		1,159,712	-$57
CHADx 1_1	Complications of infusion /transfusion	690	$ 1,847
CHADx 1_2	Gas embolism	6	$ 2,186
CHADx 1_3	Failed or difficult intubation	433	$12
CHADx 1_4	Other haemorrhage & haematoma complicating a procedure	5,064	$ 2,885
CHADx 1_5	Accidental puncture/lac during proc	1,991	$ 1,640
CHADx 1_6	Foreign body or substance left following procedure	40	$ 5,215
CHADx 1_7	Other comps of surgical and medical NEC (Incl shock T81.1)	1,543	$ 3,688
CHADx 1_8	Disruption of wound	1,094	$ 9,515
CHADx 1_9	Wound infection (exc septicaemia)	2,627	$ 4,528
CHADx 1_10	Complications of cardiac and vascular implants (exc septicaemia)	3,702	$ 7,743
CHADx 1_11	Complications of genitourinary implants (exc septicaemia)	958	$ 4,165
CHADx 1_12	Complications of orthopaedic implants (exc septicaemia)	291	$11,982
CHADx 1_13	Complications of other implants (exc septicaemia)	1,214	$ 9,843
CHADx 1_14	Complications of transplants	285	$ 7,092
CHADx 1_15	Complications of reattachment and amputations	115	$ 8,888
CHADx 1_16	Post-procedural disorders: endocrine & metabolic	46	$21,869
CHADx 1_17	Post-procedural disorders: nervous system	389	$ 6,163
CHADx 1_18	Post-procedural disorders: eye & ear	119	$743
CHADx 1_19	Post-procedural disorders: circulatory system	1,947	$ 2,698
CHADx 1_20	Post-procedural disorders: respiratory system	1,558	$ 6,727
CHADx 1_21	Post-procedural disorders: digestive system	1,566	$ 6,185
CHADx 1_22	Post-procedural disorders: musculoskeletal system	98	$ 2,502
CHADx 1_23	Post-procedural disorders: genitourinary system	882	$ 2,037
CHADx 2_1	Skin Adverse effects dt systemic antibiotics	741	$ 4,075
CHADx 2_2	Other adverse effects dt systemic antibiotics	1,129	$ 6,729
CHADx 2_3	Nausea & vomiting dt antineoplastic drugs	239	$174
CHADx 2_4	Other adverse effects dt antineoplastic drugs	514	$ 1,413
CHADx 2_5	Coagulation defect dt drugs affecting blood constituents	919	$ 3,021
CHADx 2_6	Other adverse effects dt drugs affecting blood constituents	554	$ 4,896
CHADx 2_7	Nausea and vomiting dt opioids and related analgesics	212	$ 1,614
CHADx 2_8	Alterations to mental state dt opioids and related analgesics	417	$679
CHADx 2_9	Other adverse effects dt opioids and related analgesics	858	$ 1,918

CHADx 2_10	Adverse effects dt anaesthesia (Incl misadventure)	532	-$ 1,562
CHADx 2_11	Hypotension dt anaesthesia	133	$ 1,353
CHADx 2_12	Alterations to mental state dt anaesthesia	102	$ 1,434
CHADx 2_13	Other adverse effects dt drugs affecting C-V system	708	$925
CHADx 2_14	Hypotension dt drugs affecting C-V system	328	$ 1,024
CHADx 2_15	Adverse effects dt insulin & oral hypoglycaemics	39	$ 5,103
CHADx 2_16	Adverse effects dt other drugs	3,954	$ 3,217
CHADx 2_17	Anaphylactic shock dt correct drug properly administered	89	-$ 4,044
CHADx 2_18	Incorrect drug dosage/ combination administered	256	$ 5,245
CHADx 3_1	Falls with fractured neck of femur	124	$12,002
CHADx 3_2	Falls with intracranial injury	58	$ 2,052
CHADx 3_3	All other falls	2,347	$ 3,910
CHADx 3_4	Injury d/t assault	51	$ 8,953
CHADx 3_5	Other patient accidents (exc poisoning)	1,403	$ 5,193
CHADx 4_1	Septicaemia	4,406	$ 9,420
CHADx 4_2	Mycoses	2,390	$ 6,034
CHADx 4_3	MRSA	352	$19,892
CHADx 4_4	Other drug resistant infections	978	$12,298
CHADx 4_5	Other infectious agents	742	$ 8,004
CHADx 5_1	AMI	2,201	$833
CHADx 5_2	Pulmonary embolism (PE)	485	$ 1,918
CHADx 5_3	Cardiac arrythmias, conduction disturbances & abnormal heart beat	13,564	$ 1,265
CHADx 5_4	Ventricular fibrillation/ cardiac arrest	1,590	-$347
CHADx 5_5	Heart failure	2,891	-$128
CHADx 5_6	Hypotension (not drug induced)	10,551	$ 1,085
CHADx 5_7	Cerebro-vascular disease & TIA	1,093	$ 4,237
CHADx 5_8	Venous thrombosis/embolism (not progressing to PE)	1,209	$ 6,991
CHADx 5_9	Unstable and other angina	598	$ 1,777
CHADx 5_10	Cardiogenic and other shock	400	-$ 2,585
CHADx 5_11	Other circulatory system complications	966	$ 6,690
CHADx 6_1	ARDS, respiratory failure & pulmonary collapse (incl atelectasis)	5,087	$ 3,639
CHADx 6_2	Aspiration pneumonia	1,136	$ 4,174
CHADx 6_3	Acute lower respiratory infections (incl influenza & pneumonia)	5,064	$ 5,517
CHADx 6_4	Pulmonary oedema, pneumothorax & pleural effusion	3,122	$ 5,118
CHADx 6_5	Haemorrhage from respiratory passages	1,045	$ 3,388
CHADx 6_6	Asphyxia & respiratory arrest	846	$878
CHADx 6_7	Breathing difficulties	1,429	$ 1,874
CHADx 6_8	Other hospital-acquired respiratory disorders	1,601	$ 7,503

CHADx 7_1	Gastro enteritis	4,592	$ 4,700
CHADx 7_2	Paralytic ileus & intestinal obstruction (w/o hernia)	1,195	$ 4,087
CHADx 7_3	Enterocolitis dt Clostridium difficile	233	$19,745
CHADx 7_4	Constipation	5,749	$ 3,312
CHADx 7_5	Nausea and vomiting	6,744	$440
CHADx 7_6	GI bleeding not classified to a disease	1,804	$ 4,211
CHADx 7_7	Other digestive system disorders	3,065	$ 6,876
CHADx 8_1	Pressure ulcers	2,873	$ 8,461
CHADx 8_2	Cellullitis	997	$ 2,749
CHADx 8_3	Dermatitis, rash & other skin effects	5,468	$ 2,920
CHADx 8_4	Other skin disorders	1,208	$ 5,366
CHADx 9_1	Acute & unspecified renal failure (exc post procedural)	3,608	$ 2,550
CHADx 9_2	UTIs	6,714	$ 3,675
CHADx 9_3	Urinary retention	3,898	-$43
CHADx 9_4	Other complications & symptoms of the urinary system	4,706	$787
CHADx 9_5	Other complications of male & female genitals	741	$ 3,375
CHADx 10_1	Depressive episode & symptoms involving emotional state	2,252	$ 3,141
CHADx 10_2	Panic and other anxiety disorders	743	$ 3,425
CHADx 10_3	Adjustment & other psych disorders	450	$ 6,157
CHADx 10_4	Alterations to mental state	5,442	$ 2,062
CHADx 10_5	Mental & behavioural disorders due to psychoactive substance use	597	$114
CHADx 10_6	Patient self-harm (Incl intentional and undetermined intent overdose)	262	$ 6,953
CHADx 11_1	Complications of abortion, ectopic and molar pregnancies	3,768	$342
CHADx 12_1	Foetal heart rate abnomalies	4,939	$145
CHADx 12_2	Foetal meconium and other distress	3,831	-$14
CHADx 12_3	Complications of umbilical cord	8,323	-$202
CHADx 12_4	Unsuccessful Interventions during labour	1,657	$405
CHADx 12_5	Complications of maternal anaesthetic	436	-$ 1,357
CHADx 12_6	First degree and unspecified perineal laceration	4,657	-$139
CHADx 12_7	Second degree perineal laceration	13,098	-$114
CHADx 12_8	Third degree and fourth degree perineal laceration	1,166	-$604
CHADx 12_9	Maternal haemorrhage	11,556	$170
CHADx 12_10	Other obstetric injury	4,198	-$525
CHADx 12_11	Other complications intrapartum & postpartum	5,302	$19
CHADx 12_12	Retained placenta	969	-$229
CHADx 12_13	Maternal infection (exc wound infection & septicaemia)	1,156	$ 1,032
CHADx 12_14	Breast disorders associated with childbirth	11,184	-$108

CHADx 12_15	Other disorders predominantly related to pregnancy	323	-$754
CHADx 13_1	Prenatal injuries	2,372	-$479
CHADx 13_2	Intracranial haemorrhage, hypoxia and other brain injuries	2,388	$ 2,815
CHADx 13_3	Other birth trauma	2,164	-$116
CHADx 13_4	Respiratory distress of newborn	5,821	-$682
CHADx 13_5	Aspiration & other respiratory disorders of newborn	3,121	$ 3,429
CHADx 13_6	Circulatory disorders of newborn	1,938	$867
CHADx 13_7	Perinatal infections (exc septicaemia)	3,332	$ 2,838
CHADx 13_8	Haemorrhage and blood disorders of newborn	1,005	$629
CHADx 13_9	Jaundice	6,600	-$577
CHADx 13_10	GI and feeding disorders of newborn	11,103	$737
CHADx 13_11	Other neonatal complications	12,459	$513
CHADx 14_1	Post haemorrhagic anaemia (not post-procedural)	2,751	$ 3,118
CHADx 14_2	Other hospital-acquired anaemia	5,529	$ 2,897
CHADx 14_3	Coagulation defects	1,383	$ 2,874
CHADx 14_4	Agranulocytosis, thrombocytopenia & other blood disorders	2,596	$ 6,116
CHADx 15_1	Dehydration / volume depletion	4,374	$399
CHADx 15_2	Electrolyte disorders w/o dehydration	17,555	$ 1,316
CHADx 15_3	Hospital acquired nutrition deficiencies (incl nutritional anaemia)	1,953	$ 3,708
CHADx 15_4	Hypoglycaemia & hyperglycaemia	741	$744
CHADx 15_5	Disorders of mineral metabolism	3,501	$ 2,273
CHADx 15_6	SIADH, hyperthyroidism & other metabolic disorders	315	$ 7,023
CHADx 16_1	Hospital-acquired paralysis	628	$ 4,093
CHADx 16_2	Dystonia, tremors & gait disorders	775	$144
CHADx 16_3	Other nervous system complications	1,335	$10,478
CHADx 17_1	Major symptoms	1,605	$ 3,257
CHADx 17_2	Headache & migraine	2,228	$ 1,371
CHADx 17_3	Oedema & ascites	1,728	$ 3,973
CHADx 17_4	Chest pain	3,999	$ 1,368
CHADx 17_5	Abdominal pain	1,504	$ 1,662
CHADx 17_6	Fever (not classified to condition)	4,805	$ 1,074
CHADx 17_7	Convulsions	716	$ 2,354
CHADx 17_8	Dizziness, fainting & blackout	2,191	$621
CHADx 17_9	Complications of the eye and ear	1,498	$ 4,062
CHADx 17_10	Musculoskeletal complications (not associated with falls)	3,813	$ 2,596
CHADx 17_11	Dysphagia	903	$ 1,199
CHADx 17_12	Other hospital-acquired symptoms	1,979	$ 1,482

Table 3 reports the ten CHADx that generate the highest additional costs per episode. These are generally low volume diagnoses with very costly consequences, the exception being septicaemia, with both high per episode costs and reasonably high volume of cases. Two of the top ten are drug resistant infections (Methicillin Resistant Staph Aureus (CHADx 4.3) and Vancomycin or other drug-resistant infections (CHADx 4.4)). These and others in the top 10, such as wound disruption/dehiscence (CHADx 1.8) and in-hospital falls resulting in hip fracture (CHADx 3.1) feature in most prevention/ patient safety programs.

Table 3: Top 10 Complications (CHADx) by additional cost per episode

CHADx	*Descriptor*	*N of cases*	*Additional cost per episode*
1_16	Post-procedural disorders: endocrine & metabolic	46	$ 21,869
4_3	MRSA	352	$ 19,892
7_3	Enterocolitis due to *Clostridium difficile*	233	$ 19,745
4_4	Other drug resistant infections	978	$ 12,298
3_1	Falls with fractured neck of femur	124	$ 12,002
1_12	Complications of orthopaedic implants (exc septicaemia)	291	$ 11,982
16_3	Other nervous system complications	1,335	$ 10,478
1_13	Complications of other implants (exc septicaemia)	1,214	$ 9,843
1_8	Disruption of wound	1,094	$ 9,515
4_1	Septicaemia	4,406	$ 9,420

Table 4 reports the top ten CHADx in terms of additional system costs (per episode by the number of instances). Septicaemia heads this list because it is both costly per episode and relatively frequent. The high volume of cases of electrolyte disorders not associated with dehydration (CHADx 15.2) results in a relatively low-cost complication ($A1,339 per episode) appearing in the top ten in terms of total system cost impact.

Table 4: Top 10 complications (CHADx) by total additional system cost

CHADx	*Descriptor*	*N of cases*	*Additional system cost*
4_1	Septicaemia	4,406	$ 41,505,215
1_10	Complications of cardiac and vascular implants (exc septicaemia	3,702	$ 28,665,676
6_3	Acute lower respiratory infections	5,064	$ 27,939,311
9_2	UTIs	6,714	$ 24,673,623
8_1	Pressure ulcers	2,873	$ 24,307,711
15_2	Electrolyte disorders w/o dehydration	17,555	$ 23,095,970
7_1	Gastro enteritis	4,592	$ 21,582,217
7_7	Other digestive system disorders	3,065	$ 21,076,154
7_4	Constipation	5,749	$ 19,042,144
6_1	ARDS, respiratory failure & pulmonary collapse	5,087	$ 18,509,336

Our econometric model produced 18 negative coefficients of which 15 were statistically significant. An inspection of Table 2 shows that four of these negative coefficients were associated with anaesthesia and 11 with childbirth. It is not clear why this might be the case, although it is likely that the negative coefficients reflect complex interactions between the individual CHADx when they co-occur within the same admission. Alternatively, some CHADx may truly be cost reducing in any single episode. For example, anaesthetic complications could lead to cancellation of surgery.

We have factored the negative values into our estimates of total system costs. Although statistically significant, the low frequencies resulted in only a small effect on total cost, and we do not believe that the negative coefficients compromise our ability to interpret findings for the majority of CHADx. In total, hospital-acquired diagnoses add $782 mil to the costs of inpatient care in the two states analysed here, representing 14.6% of total expenditures; and additional costs of 17.1%.

Discussion

Patient safety programmes are usually initiated with little or no evaluation of priorities. More rational priority-setting would involve evaluation of several dimensions of the problem. Obviously, the expected benefits for patient survival and quality of life of preventing particular kinds of hospital-acquired illness and injury must be considered. Evidence about the effectiveness of potential interventions in reducing the rate of such

complications, and the relative costs of introducing such programs must also be considered,[18] and for research priorities, the expected value of perfect information.

Warburton[21] has argued that patient safety interventions should meet the same cost-effectiveness criteria as other medical interventions. The CHADx estimates reported here provide the basis on which the cost-effectiveness of interventions to reduce rates of these common complications could be evaluated. Expressed as an index (using the mean cost per case as denominator), our results could be extrapolated to comparable hospitals and care health systems.

This study provides for the first time estimates of the relative costliness of patient safety problems across the spectrum of patient harm, rather than for a narrower set of safety indicators. It addresses the problem highlighted by Runciman that mundane complications of care are often overlooked when priorities for patient safety interventions are evaluated.[19,20] Our analysis suggests that CHADx 4.1 *Septicaemia,* 1.10 *Complications of cardiac and vascular implants (exc septicaemia),* 6.3 *Acute lower respiratory infections (including influenza & pneumonia)*, 9.2 *Urinary Tract Infections*, and 8.1 P*ressure ulcers* represent the highest *system cost* complications in our 2-state sample of costed patient episodes. Most of these complications are common, and if not preventable in every case, are amenable to reduction in their rates.

Pressure ulcers (CHADx 8.1) are already a frequent target of prevention programs because of their implications for extended length of stay, but their financial costs have perhaps not been fully appreciated. Others complications, however, are not so commonly recognised as resulting in high per-case costs including the *Post-procedural endocrine disorders* (CHADx 1.16), and *Complications of surgical implants* (CHADx 1.13). Better understanding of the financial burden of these diagnoses, can help make the 'business case' for greater investment in research on how best to prevent them, and for evidence-based interventions.[20]

Our findings are subject to a number of limitations. They are clearly dependent on the quality of coding and prefixing of codes in hospitals. We consider the quality assurance programs for inpatient data in the two states to be robust, but we have not undertaken verification by parallel prospective data collection or independent chart review. The Victorian cost data used were from one year prior to the Queensland data. Because the period was one of low general inflation, observed cost differences between the two health systems were small, and other sources of variation in the sample were large, we did not convert the data to a single price year.

Our use of linear regression assumes that episodes with multiple CHADx reflect random combinations of complications. Clinical reasoning suggests, however, that some CHADx may frequently co-occur. To the extent that clustering exists, it may distort some of the coefficient-based CHADx costs reported here. We are currently undertaking work to better understand underlying 'syndromes' of these diagnoses when they co-occur, particularly in maternity episodes.

The cost data used in the study are not normally distributed, perhaps leading to concern that our analysis strategy should have involved log transformation of the data. We note that normality is a sufficient but not a necessary condition for application of ordinary least squares regression, particularly when samples are sufficiently large. Lumley *et al*. support this strategy, demonstrating that samples with less than 500 observations can provide unbiased estimates.[18] We believe that our data, which contains approximately 1.7 million observations, comfortably satisfies this criterion, and that policy uses of the findings are better served by interpretable cost estimates.

Earlier models tested in this study included a term for patient age and higher order polynomials of age as alternatives to a linear specification of the relationship of age and costs. While age variables were found to be significant predictors of increased treatment cost (taking the DRG into account), we have omitted them from the final model for policy reasons. It is certainly true that older patients are more vulnerable to hospital-acquired conditions.[22] If CHADx costs were to be adjusted for the patient's age through inclusion in the model, this would reduce the cost estimates for any CHADx that disproportionately affects older people, and perhaps their priority for quality improvement efforts. Of course, it would be possible to re-weight each CHADx treatment cost using the appropriate coefficients for the distribution of patients' age in the CHADx, but this is more cumbersome than simply leaving any age-related additional costs in the CHADx coefficient.

Patient safety efforts frequently focus on dramatic but rare complications with very serious patient harm. Useful information to reduce morbidity across the severity spectrum requires a comprehensive list of events ('preventable' or not with current clinical knowledge). Adding an economic dimension to priority-setting could result in changes to the priorities of patient safety programs, and would allow for cost-utility evaluation of existing prevention programs. Such information may suggest future research directions, including study of causes and solutions for 'mundane' adverse events that cause patient harm and increase inpatient costs.

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