How different are complications that affect the older adult inpatient?

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ABSTRACT

Objective The incidence and cost of complications occurring in older and younger inpatients were compared.

Design Secondary analysis of hospital-recorded diagnosis and costs for multiday-stay inpatients in 68 public hospitals in two Australian states.

Main outcome measures A complication is defined as a hospital-acquired diagnosis that required additional treatment. The Australian Classification of Hospital-Acquired Diagnoses system is used to identify these complications.

Results Inpatients aged >70 years have a 10.9% complication rate, which is not substantially different from the 10.89% complication rate found in patients aged <70 years. Examination of the probability by single years, however, showed that the peak incidence associated with the neonatal period and childbirth is balanced by rates of up to 20% in patients >80 years. Examining the adult patient population (40–70 years), we found that while some common complications are not age specific (electrolyte disorders and cardiac arrhythmias), others (urinary tract and lower respiratory tract infections) are more common in the older adult inpatient.

Conclusion For inpatients aged >70 years, the risks of complications increase. The incidence of hospital-acquired diagnoses in older adults differs significantly from incidence rates found in younger cohorts. Urinary tract infection and alteration to mental state are more common in older adult inpatients. Surprisingly, these complexities do not result in additional costs when compared with costs for the same complications in younger adults. Greater awareness of these differing patterns will allow patient safety efforts for older patients to focus on complications with the highest incidence and cost.

The surveillance of adverse events in inpatient treatment plays a vital role in the process of risk minimisation. While there is a rich literature examining the incidence of “adverse events”,^{1–3} studies that have focused on adverse events in older adults are limited. Older adults are of concern because they are known to be at risk of an adverse event; however, estimates of incidence rates are variable.^{4–6} Knowledge about adverse events that affect the treatment of older adults is also fragmentary. For example, older adults are reportedly prone to inpatient medication errors,^{7–9} falls^{10 11} and postoperative complications.¹² Yet, we could find no comprehensive overview of hospital-acquired complications (including but not limited to adverse events) that affect older adults, nor any that estimated their impact on the relative costs of

care. Our aim is to report on hospital-acquired diagnoses and their relative costs in the older adult using routine data from 68 public hospitals in two Australian states.

METHODS

We conduct a secondary analysis of administrative cost data. Ordinary least squares regression is used to estimate the effect that hospital-acquired diagnoses have on the cost of an inpatient admission. In 2005–2006, separations from public hospitals located in Queensland and Victoria comprised 45.3% of the Australian total.¹³ Administrative data were supplied by 105 public hospitals. However, our sample of 1.69 million separations was limited to those larger public hospitals (45 hospitals in Victoria and 23 in Queensland) that were able to provide valid patient-level cost data. Thus, our analysis examined 84% of the 2.02 million public hospital separations that occurred within these two states during 2005–2006.¹³ Patients older than 70 years (n=401 676) represent 23.6% of admissions in our sample. Each de-identified record contains demographic, cost and clinical data. Clinical diagnosis is recorded using the International Statistical Classification of Diseases 10th Revision Australian Modification (ICD-10-AM)¹⁴ The data contain a principal diagnosis code with capacity for 39 additional diagnosis codes. Codes are assigned by coders using the full set of clinical notes.¹⁵

The dataset contains a condition-onset flag to indicate if the coded diagnosis was present on admission or arose during the course of the episode.¹⁶ Chronic and long-term conditions are not eligible for flagging as “hospital acquired” and were removed from further analysis using a data-cleaning algorithm.¹⁷ The clinical consequences of a hospital-acquired diagnosis can result in multiple codes being assigned to a single clinical admission. We use the Australian Classification of Hospital-Acquired Diagnoses (hereafter CHADx)¹⁸ to group these “not present on admission” ICD codes into 144 clinically meaningful classes, to estimate the relative incidence and costs of different types of complications in the older adult. However, an episode of care may include multiple CHADx cases. For example, 5.8% of inpatients older than 70 years recorded two or more CHADx and accounted for 80.8% of all recorded CHADx (see table 1).

Total costs are estimated using clinical costing systems that link individual utilisation of inpatient services (days of ward care, minutes in theatre, number and type of x ray) by the patient’s medical record number. Costs of these services are estimated from the hospital’s general ledger using cost-allocation formulae (eg, salaries in theatre, diagnostic radiology

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Table 1 Frequency of hospital-acquired diagnoses in patients older than 70 years and those aged 40–70 years

	Age >70 years		Age 40–70 years	
	Frequency	%	Frequency	%
All inpatients	401 676	100	679 328	100
Inpatients with nil CHADx	357 799	89.1	634 354	93.4
Inpatients with ≥ 1 CHADx	43 877	10.9	44 974	6.6
Inpatients with >1 CHADx	23 308	5.8	27 457	4.0
All CHADx	107 362	n.a.	95 788	n.a.

Source: Public hospital administrative data supplied by the Victorian and Queensland Health Departments, 2005–2006.

CHADx, Classification of Hospital-Acquired Diagnoses; n.a., not applicable.

relative value scale, etc)¹⁹ and are reported in 2006 Australian dollars (\$A).

Ordinary least squares regression is used to estimate the cost of each CHADx. We control for the underlying cost of an uncomplicated admission by using the mean cost of admissions without complication, classified by Diagnosis Related Group (DRG), and this is subtracted from the total cost of each patient with a CHADx to calculate an “adjusted cost”. We include two covariates in our model: a dummy variable equal to 1 if the inpatient died in hospital (DIH), and a second dummy variable for cases treated and discharged on the same day. These were included to control for the possibility that the costs of any CHADx associated with in-hospital death would be confounded by this association, and, similarly, that same-day patients would have systematically different costs from those of multiday-stay inpatients. Using STATA 10.1,²⁰ we estimated the following econometric model:

$$\text{Adj.Cost} = \alpha_0 + \alpha_1 \text{CHADx}_{1\text{to}144} + \alpha_2 \text{DIH} + \alpha_3 \text{Same.day} + \varepsilon$$

The reported “system cost” represents the regression estimate multiplied by the frequency for each CHADx—that is, the total cost in the two-state sample reported here.

The frequencies of all CHADx are plotted against age. The analysis is then focused on the frequencies and costs of CHADx in adults older than 70 years of age. Our results are presented in two league tables. The first lists the 20 most frequent CHADx and the second lists the 20 most costly CHADx that affect older

adults. The league tables contrast our results in older and younger adults.

RESULTS

Figure 1 illustrates that the frequency and proportion of admissions associated with a hospital-acquired diagnosis vary with patient age. The horizontal axis plots age. The left axis measures the frequency of any hospital-acquired diagnosis, while the right axis measures the proportion of admissions associated with a hospital-acquired diagnosis.

The frequency of hospital-acquired diagnoses in newborns is high. Thereafter, the frequency drops and remains low throughout childhood. Ages 20–40 years are associated with a rise and then fall in hospital-acquired diagnosis rates, principally relating to childbirth. For example, CHADx 12.7 second-degree perineal laceration is the most common complication in this age group (12 243 cases). After the age of 40 years, the frequency of any complication increases steadily until the age of 80 years.

The proportion of admissions with a hospital-acquired diagnosis, by age, follows a similar trend, until age 80 years, when, instead of declining, it increases with each additional year of age. While nearly 20% of adults older than 80 years of age incur a hospital-acquired diagnosis, when the data are partitioned into admissions of patients <70 and >70 years, the mean for older inpatients (10.89%) is not significantly different from that for younger inpatients (10.9%). As higher rates of hospital-acquired diagnoses associated with childbirth had the potential to confound a comparative analysis in older adult, inpatients aged 40–70 years were selected as the appropriate comparator.

Older inpatients (>70 years) who develop a hospital-acquired diagnosis have a mean cost of treatment (\$A14355) that is 5.9 times greater than inpatients that do not experience one (\$A2448). By way of contrast, inpatients aged between 40 and 70 years who develop a hospital-acquired diagnosis have a mean cost of treatment (\$A15919) that is 6.5 times larger than inpatients who do not (\$A2138).

Table 2 presents the 20 most frequently occurring individual CHADx, comparing inpatients aged >70 years with the

Figure 1 The frequency of any hospital acquired diagnosis in Queensland and Victoria (by age). Source: Public hospital administrative data supplied by the Victorian and Queensland Health Departments, 2005–2006. Graph was truncated at 95 years of age due to small sample sizes.

Table 2 Twenty most frequent CHADx in patients older than 70 years versus those aged 40–70 years

CHADx	Description	Age >70 years				Age 40–70 years			
		Rank of frequency	Frequency	%	Total cost \$m	Rank of frequency	Frequency	%	Total cost \$m
15.2	Electrolyte disorders w/o dehydration	1	8437	7.86	\$11.7	1	6902	7.21	\$5.9
5.3	Cardiac arrhythmias, conduction disturbances	2	6899	6.43	\$9.1	2	5196	5.42	\$5.9
5.6	Hypotension (not drug induced)	3	5201	4.84	\$6.1	3	4343	4.53	\$3.6
9.2	UTIs	4	4313	4.02	\$10.2	11	1917	2	\$10.3
10.4	Alterations to mental state	5	3526	3.28	\$5.0	17	1604	1.67	\$7.6
7.4	Constipation	6	2916	2.72	\$7.1	9	2040	2.13	\$9.1
6.3	Acute lower respiratory infections (including influenza and pneumonia)	7	2719	2.53	\$11.1	13	1781	1.86	\$11.1
9.4	Other complications and symptoms of the urinary system	8	2582	2.4	\$2.9	16	1630	1.7	\$1.5
14.2	Other hospital-acquired anaemia	9	2402	2.24	\$5.0	8	2077	2.17	\$7.0
15.1	Dehydration/volume depletion	10	2390	2.23	\$1.9	19	1467	1.53	\$0.7
9.1	Acute and unspecified renal failure (excluding postprocedural)	11	2246	2.09	\$5.3	27	1186	1.24	\$5.8
8.3	Dermatitis, rash and other skin effects	12	2199	2.05	\$5.9	10	1967	2.05	\$6.9
6.1	ARDS, respiratory failure and pulmonary collapse (including atelectasis)	13	2151	2	\$6.5	7	2220	2.32	\$5.7
9.3	Urinary retention	14	2057	1.92	\$0.7	24	1345	1.4	\$0.7
7.1	Gastroenteritis	15	2037	1.9	\$7.7	12	1826	1.91	\$9.6
5.5	Heart failure	16	2001	1.86	\$0.0	37	795	0.83	\$2.4
1.4	Postprocedural haemorrhage and haematoma	17	1899	1.77	\$4.8	5	2432	2.54	\$7.4
7.5	Nausea and vomiting	18	1895	1.77	\$1.6	4	3141	3.28	\$0.0
8.1	Pressure ulcers	19	1834	1.71	\$8.8	35	809	0.84	\$12.8
5.1	AMI	20	1717	1.6	\$2.5	57	470	0.49	\$0.9

Source: Public hospital administrative data supplied by Victorian and Queensland Health Departments, 2005–2006.

AMI, acute myocardial infarction; ARDS, acute respiratory distress syndrome; CHADx, Classification of Hospital-Acquired Diagnoses; UTI, urinary tract infection.

corresponding frequency and cost of the same complication in inpatients aged 40–70 years.

The top three complications have the same ranks in the two age groups, indicating that these are commonly occurring hospital-acquired diagnoses, regardless of patient age. However, below this, a distinctive pattern arises for older adult inpatients, with CHADx 9.2 (urinary tract infections) ranking 4th for the older adult, but 11th for younger adults, and CHADx 10.4 (alterations to mental state) ranking 5th among the older adult, in contrast to a ranking of 17th among the younger inpatient population. Older patients have more than twice the rate of pressure ulcers (CHADx 8.1) and three times the rate of hospital-acquired acute myocardial infarction (CHADx 5.1).

Table 3 shows the partial regression coefficients for control variables, while table 4 lists the regression-estimated cost of the 20 highest-cost CHADx in the older adult (with the corresponding cost ranks in younger adult patients (40–70 years)). The signs on these coefficients are as expected. Dying in hospital is cost-saving. Same-day inpatients are less costly than multiday patients are. The model included dummy variables for 144 CHADx classes, of which 28 were dropped because they were

not clinically relevant to the older adult (eg, prenatal injuries (CHADx 13.1)).

The dependent variable in this analysis is the net cost per patient once the mean cost of uncomplicated admissions in the relevant DRG class has been removed. Thus, the net effect of a CHADx on cost is given by adding the intercept term to the CHADx coefficient. In total, 105 of the 116 remaining CHADx codes increase the cost of an admission, of which 99 were statistically significant at the 95% level of confidence.

Our econometric model also produces seven negative coefficients that are statistically significant. These CHADx are associated with anaesthesia. It is not clear why these hospital-acquired diagnoses would reduce the cost of an admission. Perhaps the data contain insufficient detail to control for patient acuity; alternatively, CHADx may truly be cost reducing. For example, anaesthetic complications could lead to cancellation of surgery. Although unexpected, the absolute size of these negative coefficients is not large and does not detract from our ability to interpret findings.

Table 4 illustrates the fact that total system cost reflects an interaction between the number of cases and the additional cost for each case. In older inpatients, although CHADx 15.2 (electrolyte disorder (without dehydration)) is less costly per patient than other CHADx, the frequency of this complication makes it more costly to the system. By way of contrast, electrolyte disorder (without dehydration) is the 21st most costly complication among adults aged 40–70 years. Conversely, the highest-impact complication in the younger group (septicaemia (CHADx 4.1)) adds \$A7689 per older patient episode, but with fewer cases, ranks only 5th for this group.

A divergence is apparent between the younger cohort and patients >70 years in patterns of complication costs. Hypotension (CHADx 5.6) and falls (excluding those with fractured neck

Table 3 Regression results

Dependent variable; adjusted cost	Coefficient	SE	t score	p Value
Intercept	4.05	11.70	0.35	0.729
Same-day inpatient	−41.64	13.94	−2.99	<0.01
Died in hospital	−1012.74	41.05	−24.67	<0.01
R ²	0.26			

Source: Public hospital administrative data supplied by Victorian and Queensland Health Departments, 2005–2006.

The coefficients for the 144 CHADx classes are not shown in table 3.

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Table 4 Twenty most costly complications in patients older than 70 years versus those aged 40–70 years

CHADx	Description	Coefficient	Frequency	Cost \$m	Rank cost (>70 years)	Rank cost (40–70 years)
15.2	Electrolyte disorders w/o dehydration	1386.2	8437	\$11.7	1	21
6.3	Acute lower respiratory infections (including influenza and pneumonia)	4096.8	2719	\$11.1	2	4
9.2	UTIs	2364.1	4313	\$10.2	3	5
5.3	Cardiac arrhythmias, conduction disturbances	1324.3	6899	\$9.1	4	20
4.1	Septicaemia	7689.3	1154	\$8.9	5	1
8.1	Pressure ulcers	4820.9	1834	\$8.8	6	2
7.1	Gastroenteritis	3766.0	2037	\$7.7	7	6
7.4	Constipation	2434.6	2916	\$7.1	8	8
7.7	Other digestive system disorders	6207.2	1131	\$7.0	9	7
1.10	Complications of cardiac and vascular implants (excluding septicaemia)	5733.1	1216	\$7.0	10	3
6.1	ARDS, respiratory failure and pulmonary collapse (including atelectasis)	3042.6	2151	\$6.5	11	18
5.6	Hypotension (not drug induced)	1164.3	5201	\$6.1	12	39
8.3	Dermatitis, rash and other skin effects	2670.6	2199	\$5.9	13	13
6.4	Pulmonary oedema, pneumothorax and pleural effusion	4298.0	1342	\$5.8	14	9
3.3	All other falls	3700.9	1519	\$5.7	15	36
9.1	Acute and unspecified renal failure (excluding postprocedural)	2370.6	2246	\$5.4	16	17
14.2	Other hospital-acquired anaemia	2087.4	2402	\$5.0	17	12
10.4	Alterations to mental state	1411.3	3526	\$5.0	18	10
4.2	Mycoses	4410.7	1117	\$4.9	19	15
1.9	Wound infection (excluding septicaemia)	6643.7	726	\$4.8	20	19

Source: Public hospital administrative data supplied by the Victorian and Queensland Health Departments, 2005–2006.

ARDS, acute respiratory distress syndrome; CHADx, Classification of Hospital-Acquired Diagnoses; UTI, urinary tract infection.

of femur or with intracranial injury) (CHADx 3.3) would not even appear in the top 20 total system cost for younger adults (ranks 39 and 36, respectively). In general, the largest system cost-impact complications in the older adult are more common ones such as urinary tract infections, pneumonias and cardiac arrhythmias, with lower per-case costs.

DISCUSSION

Improving outcomes for older adult inpatients is going to require taking a broader view than the current literature allows. Previous studies have focused on individual sources of harm to older adult inpatients but did not place these in the context of all hospital-acquired illness and injury. Priority setting for patient safety programmes needs to take into account the frequency and the total system cost of hospital-acquired diagnoses.

The aggregation of inpatient complications by clinical type provides a global perspective of the burden of hospital-acquired disease. Cardiovascular complications are most frequent in adults over 70 years (4.8%), with metabolic and genitourinary complications occurring in 3.5% and 2.9% of inpatients aged over 70 years, respectively. Although only sixth ranked by volume, postprocedural complications are the most costly in the sample, representing 15.4% of excess costs attributable to complications in the older adult. Analysis of the 144 CHADx classes provides specific details about relative frequency and costs. We demonstrate that the hospital-acquired diagnoses that affect older adults are qualitatively distinct. Older adults are particularly prone to urinary tract infections (CHADx 9.2), alterations to mental state (CHADx 10.4) and lower respiratory tract infections (CHADx 6.3).

By using multivariate regression to analyse costs, we are able to distinguish those costs that are attributable to the patient's primary diagnosis from those that can be attributed to other

causes, including hospital-acquired conditions. In older adult inpatients, CHADx 15.2 (electrolyte disorders (without dehydration)) are more costly to the system than CHADx 4.1 (septicaemia).

Our aim was to utilise routine hospital data to describe the epidemiology of a broader range of complications that affect the older adult inpatient. Bates *et al* said:

"[t]he 'holy grail' in computerized adverse event detection has been a tool to detect a large fraction of all adverse events... Such a tool could be used by hospitals for routine detection of adverse events on an ongoing basis and in real time."²¹

The condition-onset marker enabled the CHADx coding algorithm to distinguish pathophysiology, which was present on admission from conditions, which developed subsequently. Quite obviously, it is not possible to prevent all hospital-acquired illness and injury. Nevertheless, identified adverse events may miss a range of preventable complications of care, which jeopardise patient recovery and add to healthcare system costs.

Our data, which were obtained from 68 public hospitals and comprise 84% of all public separations, could bias cost estimates if the selected hospitals implement clinical protocols that were systematically different from non-selected hospitals. However, hospital audits by the Australian Council on Healthcare Standards²² and the registration of various healthcare professionals by state medical and nursing boards are designed to ensure a consistent, minimum standard of patient treatment.

Our findings, however, are clearly dependent on the quality of coding and prefixing of diagnoses in hospitals. Although we consider the quality assurance programs in the two public hospital systems to be robust, we have not verified coding quality. We are not able to attribute causation or preventability with the data reported here; however, we consider that judicious

analysis of administrative data offers a cost-effective method to evaluate interventions designed to reduce complications of inpatient care. CHADx may be useful as a screening tool to estimate rates and patterns of untoward in-hospital outcomes in the older adult and other inpatient subpopulations of interest.

Economic priorities for patient safety programmes should obviously factor in the expected benefits for patient survival and quality of life of preventing particular kinds of complications. A better understanding of the financial burden of these complications can help make the “business case” for greater investment in evidence-based patient safety programmes and in further research on how best to prevent inpatient harms.

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