

# Adverse events in Victorian admissions for elective surgery

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## Abstract

**Objectives:** To investigate a method to identify and understand patterns of adverse events by utilising secondary data analysis; to identify the types of complications associated with elective surgery; to identify any specific “adverse event-prone” elective procedures; and to consider the implications of these patterns for hospital patient safety programs.

**Setting:** Public hospitals in Victoria.

**Design:** Secondary analysis of data on acute hospital admissions for elective surgery in the period 1 July 2000 to 30 June 2001, for non-obstetric patients older than 15 years ( $n = 177\,533$ ).

**Main outcome measures:** Estimated rates of adverse events for the most commonly performed elective surgery procedures; frequency of the most commonly recorded adverse event types.

**Results:** Of all admissions, 15.5% had at least one complication of care. The most frequent first-recorded single complication code, in 9.6% of cases with a complication, was “Haemorrhage and haematoma complicating a procedure”. The most common adverse event categories were cardiac and circulatory complications (23%), symptomatic complications (18%), and surgical and drug-related complications (17%). The procedure blocks most frequently associated with an adverse event were coronary artery bypass surgery (67%), colectomy (52%), hip and knee arthroplasty (42% and 36%, respectively), and hysterectomy (20%). The types of complications associated with the four most adverse event-prone procedures were cardiac arrhythmias, surgical adverse events (haemorrhage or laceration), intestinal obstruction, anaemia, and symptomatic complications.

**Conclusion:** Routinely collected data are valuable in obtaining information on complication types associated with elective surgery. International Classification of Diseases codes and surgical procedure “blocks” allow very sophisticated inves-

## What is known about the topic?

Preventing adverse events is a primary focus of patient safety approaches in hospitals, and access to reliable data is an important prerequisite for this work. Adverse events associated with surgical procedures are the most common.

## What does this paper add?

This paper demonstrates that secondary analysis of ICD codes in an existing hospital dataset can generate useful information about the rates and patterns of adverse events, and confirms that patient age is a risk factor in adult elective surgery patients. The highest complication rate is associated with coronary artery bypass surgery.

## What are the implications?

Hospital safety programs could benefit from sophisticated analysis of their coding data, benchmarked with that of their peers. The benefit will be greater with better coding quality. ◆

tigation of types of complications and differences in complication rates for different surgical approaches. The usefulness of such data relies on good documentation in the medical record, thorough coding and periodic data audit. The limitations of the method described here include the lack of follow-up after discharge, variable coding standards between institutions and over time (potentially distorting information on rates), lack of information on the causative factors for some adverse events, and a limited capacity to support investigation of particular cases. Hospitals should consider monitoring complication rates for individual elective procedures or blocks of similar procedures, and comparing adverse event rates over time and with peer hospitals as an integral part of their patient safety programs.

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REGULAR MEDIA REPORTS continue to raise public awareness of the difficulty hospitals face in monitoring patient safety and ensuring the delivery of quality health care.<sup>1-4</sup> High-profile inquiries in

three states have brought to public notice the lack of systems for identifying and reporting patient safety issues.<sup>5-7</sup> The Victorian Auditor-General's recent report (2005) *Managing patient safety in public hospitals*<sup>8</sup> recommended firmer guidelines for managing clinical incidents and system-wide implementation of minimum reporting standards to monitor patient safety in hospitals.

Studies have shown that half to three-quarters of adverse events can be attributed to surgical care, and surgical management of disease is complex and difficult.<sup>9</sup> Australian studies on adverse events in surgical patients have found high rates of complications. Kable et al<sup>10</sup> found an adverse event rate of 17.2% for nine high volume elective procedures, these being a third of all surgical admissions. A second study of serious postoperative events in an Australian teaching hospital found the incidence rate of serious adverse events was 16.9%.<sup>11</sup>

Studies such as the Harvard Medical Practice Study<sup>12</sup> and the landmark Quality in Australian Health Care study modelled on the Harvard study<sup>13</sup> have contributed considerably to our understanding of the nature and cause of adverse events, as have other analyses of surgical errors and complications.<sup>9,14-16</sup> In these studies, however, emergency and elective procedures have been investigated together, despite considerable differences in the risks for adverse events. Incident and prevalent cases were considered together, although patient safety programs are primarily concerned with complications arising in the index hospital admission.

Elective surgical management is more controlled than is emergency surgery. The literature shows that trauma and emergency or unplanned

procedures contribute considerably to a higher risk of adverse events, and that surgeons report more systems failures in emergency surgical care.<sup>9-11</sup> For this reason, we were interested to understand the patterns of adverse events occurring in Victorian public hospitals under the relatively controlled conditions of elective (non-emergency) surgery. We aimed to identify types of adverse events or complications associated with elective surgery, and any procedures associated with a higher rate of adverse events (for lack of a better term, we have described these procedures as "adverse event-prone"), with a view to learning how these data might be used in hospital patient safety programs.

## Methods

### *Data source and sample*

The data source for this analysis is the Victorian Admitted Episodes Dataset (VAED) containing de-identified demographic and clinical data on all Victorian public and private hospital separations for the financial year 2000–01. Clinical data (diagnoses and procedures) are generated at hospital level by clinical coders from review of the medical record, using codes from the International Statistical Classification of Diseases and Procedures, Tenth Revision (ICD-10-AM).<sup>17</sup> In Victoria, all public and private acute hospitals are required to report a minimum admitted patient data set on a monthly basis to the VAED. From the initial data file ( $n = 1\,645\,992$ ) only multi-day elective (non-maternity, non-emergency) admissions to public hospitals were selected.

Although preliminary analysis showed that almost 70% of cases admitted electively to Victorian hospitals were same-day patients, these episodes were not investigated. Given the short stay, many complications would not manifest before the patient was discharged, and when these require additional care, they would be treated by general practitioners, in surgeons' rooms, or result in a subsequent readmission where the complication would be coded as pre-

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existing. Thus, adverse events of same-day episodes are often not treated in hospital, and, when they are, may be difficult to attribute to the index episode of care. This will also be true for some multi-day cases, although following these patients after discharge would require a purposive study to determine the rate of such complications. When serious complications arise during same-day surgery, however, these cases become multi-day cases, and appear in the data analysed here.

Cases were further selected only if they were classified to a surgical diagnosis related group (DRG), eliminating most admissions for minor procedures not previously eliminated as same-day admissions (the DRG grouper selects only major surgical procedures for assignment to a surgical DRG). Children (all cases 14 years and younger) were excluded because of the narrow range of surgical procedures undertaken and the concentration of surgery in a single specialist paediatric hospital. Obstetric cases were also excluded because current Victorian prefixing guidelines restrict the use of the complications prefix (see below) on the basis that timing of any adverse event (“after admission”) is difficult to establish for most obstetric events. A small number of cases were excluded where coding guidelines on prefixing of chronic conditions<sup>18</sup> were violated ( $n = 229$ ). The final data for analysis consisted of 177 553 multi-day adult elective surgical cases. Data analysis was performed using SPSS Version 11.5 for Windows (SPSS Inc, Chicago, Ill, USA) and Microsoft Excel (Microsoft Corporation, Redmond, Wash, USA).

### **Definition of an adverse event**

Defining adverse events is often contentious. We have used two sources. The Australian Council for Safety and Quality in Health Care (ACSQHC) defines an adverse event as: “An incident in which unintended harm resulted to a person receiving health care”.<sup>19</sup> In Victoria, clinical coders assign prefixes to diagnosis codes, with directions to record only diagnoses which required treatment or extended length of

stay (vol. 5<sup>17</sup>) (thus, unintended harm) and to assign a “C” (complication) prefix only when a “condition was not present at the start of this episode of care”.<sup>18</sup> It is these “C-prefixed” diagnoses which are analysed here. Neither definition requires proof of preventability or negligence, only that a harm occurred while the patient was hospitalised. In this paper, the terms “complication” and “adverse event” are thus used interchangeably. The Victorian coding standard, however, identifies the outcomes (additional diagnoses) rather than the event or events that led to these outcomes.

### **Grouping of C-prefixed diagnosis codes and procedure codes**

This study examines only the first of any C-prefixed diagnosis codes on each record. This provides an accurate estimate of the number of episodes with an adverse event, but may not accurately reflect their relative frequency when multiple complications arise in any one case. Over 1200 different diagnosis codes were assigned a C prefix. To get an overall picture of the most significant numbers in any group of complications, they were categorised into 12 major groups and further subdivided into 35 more detailed complication types based on sequences of related codes from the ICD-10-AM (see Box 1; lists of codes in each group available from the authors).

The ICD-10-AM procedure manual is organised into chapters according to body systems. Each chapter lists the procedures, which are organised into surgical blocks according to their type and complexity. For example, blocks 1518 and 1519 list all procedures related to knee arthroplasty — 10 procedures altogether. The *blocks* enable the investigation of procedure types, including different surgical approaches such as open and closed operations, for rates of complications, whereas the *chapters* assist with the identification of procedural complication rates by surgical specialty (for example, thoracic surgery procedures would be contained in the “Procedures on respiratory system” chapter).

### I Major complication categories by frequency and proportions of all first-recorded complications, Victorian Admitted Episodes Dataset 2000–01 adult multi-day elective surgery episodes

Major and sub-group complication categories	No. of episodes	% of first-recorded complications
Infection		11.3%
Surgical wound infection	996	3.6%
Sepsis	130	0.5%
Other infections (including urinary tract infection, upper respiratory, organisms)	1362	4.9%
Infections associated with implants and devices	312	1.1%
Pneumonia, pneumonitis and Mendelson's syndrome	336	1.2%
Symptoms		17.9%
Nausea and vomiting	1232	4.5%
Fever	905	3.3%
Other symptoms	2785	10.1%
Embolism and thrombosis		0.8%
DVT	124	0.4%
Embolism and thrombosis	115	0.4%
Cardiac and circulation		23.2%
Cardiac arrest resulting in death	8	0
Cardiac arrest with resuscitation	68	0.2%
Cardiac arrhythmias	2056	7.4%
Coronary infarctions	141	0.5%
Cerebrovascular infarctions	73	0.3%
Other cardiac events	1176	4.3%
Hypertension	538	1.9%
Hypotension	1177	4.3%
Anaemia	1181	4.3%
Respiratory		5.2%
Respiratory distress and failure	182	0.7%
Other respiratory events	1254	4.5%
Pain		3.6%
Pain, musculoskeletal	184	0.7%
Pain, other	791	2.9%
Injuries		1.1%
Fractures, sprains, strains, contusions	98	0.4%
Burns and other accidental injuries	138	0.5%
Open wounds	49	0.2%
Gastrointestinal		3.5%
Intestinal obstruction	431	1.6%
Other gastrointestinal events	518	1.9%

**I (continued) Major complication categories by frequency and proportions of all first-recorded complications, Victorian Admitted Episodes Dataset 2000–01 adult multi-day elective surgery episodes**

Major and sub-group complication categories	No. of episodes	% of first-recorded complications	
Ward-based management			3.7%
Decubitus ulcer and ulcer of lower limb	66	0.2%	
Metabolic, fluid and electrolyte disorders	974	3.5%	
Surgical and drug related			17.3%
Adverse events due to surgery and anaesthesia*	4536	16.4%	
Adverse drug events	248	0.9%	
Other postprocedural complications			6.8%
Other postprocedural events (end of chapter codes)	1120	4.1%	
Renal failure	189	0.7%	
Mechanical and other complications associated with implants and devices	541	2.0%	
All other first recorded complications	1566	5.7%	5.7%
Episodes with recorded complications (15.5% of sample)	27 600	100%	100%

\* Predominantly haemorrhage and haematoma (see Box 2). ◆

## Results

### Overview

The database contained 177 533 cases, of which 27 600 (15.5%) had at least one recorded complication. The complication rate increased with each age category: ages 15 to 39 had the lowest rates of adverse events (7.1%), ages 40 to 64 had a complication rate of 14.0% and 22.1% of patients aged over 65 had at least one complication.

Box 1 shows the three largest complication categories were cardiac and circulation (23.2%), symptoms (17.9%) and surgical and drug related (17.3%). The cardiac complications were dominated by arrhythmias, while the surgical complications were predominantly haemorrhage and haematoma (9.6% of all complications, see Box 2). Symptoms included nausea and vomiting, fever and a wide range of other symptoms. While symptomatic complications may seem minor, it is worth remembering that these are recorded only when they required additional treatment or prolonged a patient's stay in hospital. The fifteen most frequent first-recorded complications are shown in Box 2.

### Adverse event rates associated with procedures

Box 3 shows the 17 ICD-10-AM surgical chapters (related to body systems) and the proportion of complications in each. The four high volume chapters with high rates of complications were cardiovascular (27.5%), musculoskeletal (14.6%), digestive system (16.2%) and gynaecological procedures (15.0%). Low-volume procedure chapters with very high rates of adverse events were respiratory procedures (34.0%), procedures on blood and blood-forming organs (24.6%) and procedures on nervous system (20.6%). The lowest complication rates (below 5%) were for ear and mastoid process procedures (4.7%) and nose, mouth and throat procedures (4.2%).

Box 4 shows complication rates and volume of procedures of the most frequently-performed surgical procedures when "blocks" of similar principal procedure codes are considered. Of these, hernia repair, cholecystectomy and hysterectomy were the most frequently performed. The five procedures most frequently associated with an adverse event were coronary artery bypass, col-

## 2 The fifteen most frequent first-recorded complications as a proportion of total complications, Victorian Admitted Episodes Dataset 2000–01 adult multi-day elective surgery episodes

Rank	ICD-10-AM code	Complication	No. episodes	Episodes with any complication
1	T810	Haemorrhage and haematoma complicating a procedure	2 652	9.6%
2	I48	Atrial fibrillation and flutter	1 251	4.5%
3	R11	Nausea and vomiting	1 219	4.4%
4	I959	Hypotension unspecified	1 120	4.1%
5	T814	Infection following a procedure not elsewhere classified	996	3.6%
6	N390	Urinary tract infection	912	3.3%
7	R509	Fever unspecified	880	3.2%
8	R33	Retention of urine	826	3.0%
9	T812	Accidental puncture or laceration during procedure	753	2.7%
10	I978	Other postprocedural circulatory system disorders	733	2.7%
11	D649	Anaemia unspecified	673	2.4%
12	N998	Other postprocedural genitourinary system disorders	532	1.95%
13	I10	Essential (primary) hypertension	527	1.95%
14	J981	Pulmonary collapse	447	1.65%
15	J958	Other postprocedural respiratory disorders	434	1.6%
		All other episodes with at least one recorded complication	13 645	49.4%
		<b>Episodes with recorded complications</b>	<b>27 600</b>	<b>100.0%</b>

ectomy, hip and knee arthroplasties, and hysterectomy. Nearly two out of three patients undergoing coronary artery bypass procedures had at least one complication; more than half of all colectomy patients; four in ten patients undergoing hip replacement; and three in ten undergoing knee replacement. Two in ten hysterectomy patients experienced at least one recorded adverse event in the admission.

For coronary artery bypass (complication rate 67.2%), nearly a third of the recorded complications were cardiac arrhythmias, with an additional 11.0% attributable to both procedural complications (adverse events due to surgery and anaesthesia) and “other” respiratory events. Complications associated with colectomy procedures, the second most adverse-event prone procedure (51.6%), were more diverse, with procedural complications representing 10.0% as the largest group, and other complications including intestinal obstruction, metabolic disorders, wound

infection and arrhythmias each recording at least a 5% share of the total. For hip and knee arthroplasty (41.0% and 35.3%, respectively), anaemia, symptoms other than fever and nausea, and adverse events due to surgery were the most common complications, together representing approximately 40% of first-recorded complications for these procedures. The most frequent first-recorded complications in hysterectomy episodes were operative adverse events, infections other than sepsis or surgical wound/implant infections, and symptomatic complications.

### Comparing surgical approaches

Box 5 provides comparisons of the proportion of episodes with and without adverse events for differing surgical approaches to the same procedure. Laparoscopic cholecystectomies and transurethral prostatectomies, both minimally invasive procedures, had lower complication rates than open approaches to the respective

### 3 ICD-10-AM procedure chapters by first-recorded complications, ranked by proportion of complicated episodes, Victorian Admitted Episodes Dataset 2000–01 adult multi-day elective surgery episodes

Procedure chapter	No. complications	All episodes	Complications (%)
Respiratory procedures	954	2 805	34.0%
Cardiovascular	6002	21 821	27.5%
Non-invasive	239	951	25.1%
Blood and blood-forming organs	323	1 311	24.6%
Nervous system	1326	6 428	20.6%
Urinary system	1284	7 298	17.6%
Endocrine system	377	2 190	17.2%
Digestive system procedures	5623	34 722	16.2%
Gynaecological procedures	2471	16 486	15.0%
Musculoskeletal procedures	5806	39 740	14.6%
Male genitals	993	7 363	13.5%
Breast procedures	486	5 628	8.6%
Dental procedures	6	76	7.9%
Dermatological procedures	792	10 906	7.3%
Eye and adnexa procedures	381	7 121	5.4%
Ear and mastoid process	72	1 517	4.7%
Nose, mouth and pharynx	465	11 170	4.2%
<b>All complications</b>	<b>27 600</b>	<b>177 533</b>	<b>15.5%</b>

procedures. Transurethral and other closed prostate procedures had a complication rate of 13.6%; the open approach, 30.4%. “Closed” cholecystectomies had a complication rate just under 10%, whereas the rate was much higher for the open approach (26.5%). Many factors contribute to the choice of surgical approaches, and it may be that patients undergoing open procedures were clinically predisposed to more complications.

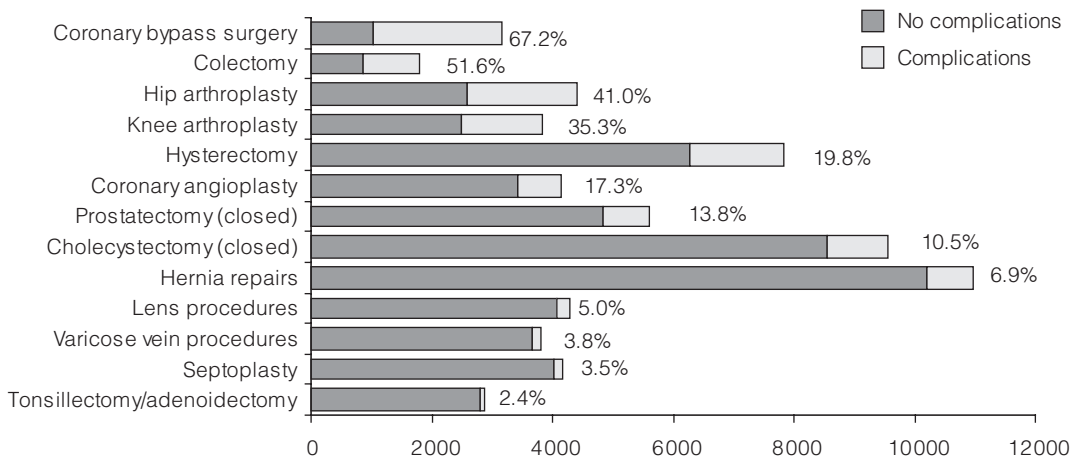
Hip revision procedures had a higher adverse event rate than primary hip replacement procedures — 46.3% and 41.0%, respectively — but this pattern was reversed for knee surgery, with a lower adverse event rate for revisions (29.1%) than for primary procedures (35.3%). Based on evidence in the literature, it was assumed that the high complication rate was due to the complex nature of the procedure, with implants playing a role in higher rates of infection or mechanical complications associated directly with the prosthesis. In this study, however, complications asso-

ciated with the implant directly (mechanical complications and infections) were found to be minimal compared to the rate of all other complications for these procedures. For hip replacements, only 69 cases (1.4% of all procedures) recorded implant-related complications as the first C-prefixed code. For knee replacements, only 43 cases (1.0%) were implant-related complications

### Discussion and conclusion

The clinical literature on complications of care for specific surgical procedures is vast, and we have not tried to review it here. We were interested, however, in understanding how the rates and patterns identified here compare with the published literature. Overall, the current study using secondary analysis of routine data provides results that are consistent with those found in purposive studies, although rates will differ

#### 4 High volume surgical episodes ranked by the proportion of complicated episodes, Victorian Admitted Episodes Dataset 2000–01 adult multi-day elective surgery episodes



because most studies include prevalent cases in their analysis. In this research, we found high rates of adverse events in coronary artery bypass surgery, colectomy, hip and knee arthroplasty, and hysterectomy.

Kable et al<sup>10</sup> rank coronary artery bypass as one of the most adverse event-prone surgical procedures. Vascular and cardiac surgery have been found to be associated with the highest adverse event rates by Bellomo et al.<sup>11</sup> Analysis of event types recorded in the VAED suggests that patient safety programs need to pay attention to arrhythmia rates, haemorrhages complicating surgical procedures and accidental punctures or lacerations, and other cardiac and respiratory events such as pulmonary collapse. While it may not be possible to predict which specific patients are at high risk, nor to determine in retrospect which specific events were preventable, comparison of rates between peer hospitals would enable them to gain understanding about differences in their patterns and rates of these events.

Hip and knee arthroplasties have high rates of complications that are not directly related to the prosthesis, as we found that implant-related mechanical complications and infections in the

current study were low, whereas the overall rate of complications is very high. More than twice as many hip replacements are performed for people over 65 years of age; for knee replacements, it is triple the amount. Age (particularly age over 74) and type of procedure are major risk factors for adverse events.<sup>10,11</sup> Ageing of the population means that there will be an increase in hip and knee replacements and revisions.<sup>20</sup> This indicates that adverse event prevention strategies will maximise their impact by focussing on ward-based and perioperative management of older patients.

Colectomy procedures (excision of the large bowel) are the second most adverse event-prone procedures, with a complication rate of nearly 52%. The five most common complications for colectomy reflect problems in both surgical and post-operative care: adverse events due to surgery, such as haemorrhage and accidental puncture; intestinal obstruction; other symptoms; metabolic, fluid and electrolyte complications; and surgical wound infection.

Kable et al<sup>10</sup> found that the incidence of adverse events for selected gynaecological procedures was 12%, comparable with the 15% rate for gynaecological procedures identified in the



### 5 Proportions of episodes with any complication by differing surgical approaches, Victorian Admitted Episodes Dataset 2000–01 adult multi-day elective surgery episodes

	No. episodes	No. episodes with complication	Episodes with any complication
Closed and open prostatectomies			
Transurethral and closed prostatectomy	5610	764	13.6%
Open prostatectomies	516	157	30.4%
Cholecystectomy, laparoscopic and open			
Laparoscopic cholecystectomy	9083	877	9.7%
Open cholecystectomies	476	126	26.5%
Hip arthroplasty and revision			
Hip arthroplasty	4401	1806	41.0%
Revision hip arthroplasties	689	319	46.3%
<b>Implant-related complications</b>	<b>5090</b>	<b>69*</b>	<b>1.4%</b>
Knee arthroplasty and knee revision arthroplasty			
Knee arthroplasty	3839	1354	35.3%
Revision knee arthroplasties	519	151	29.1%
<b>Implant-related complications</b>	<b>4358</b>	<b>43*</b>	<b>1.0%</b>

\* For arthroplasties with implant-related complications, the number of implant-related cases refers to the complications for initial and revision procedures combined. ◆

current study. Among the 20 surgical DRGs they analysed, the DRG 645 “Uterus and adnexa procedures without malignancy” had an incidence rate of 20.8%, again comparable to the complication rate of 20% for hysterectomies found in this research. Gawande et al<sup>21</sup> estimate that slightly more than half of all surgical adverse events are preventable, identifying hysterectomies as one of 12 operations with a significantly elevated adverse event incidence rate.

Many adverse events studies have examined the preventability of complications associated with surgery. Kable et al<sup>10</sup> estimated that 48% of adverse events are preventable, and Gawande et al<sup>21</sup> made a similar estimate of 54%. Studies that have analysed the causal pathway have attributed adverse events mainly to system inadequacies, including inexperience, technical error, lack of supervision, communication breakdown, fatigue and excessive workload.<sup>9,10,12,21</sup> Hardly ever is an individual surgeon solely responsible for adverse events; usually it is a chain of events or factors

preceding a surgical operation leading to preventable complications. Adverse events should thus be regarded as arising from the complexity of the clinical environment.<sup>10</sup> Hospital patient safety programs need to investigate and review common factors after defining their target areas for reducing the incidence of complications in surgical care.

In Australia, much research has been and is being undertaken into the establishment and ongoing maintenance of valuable, high quality morbidity data collections.<sup>22-29</sup> Considerable efforts are made in Australia to improve data quality through coding education and monitoring of standards. Coded data have underpinned the Victorian casemix-based funding model since its introduction in 1993. Regular audits of coded data and quality checks by the Victorian Department of Human Services are undertaken to assess usability of the data for policy purposes. Research studies undertaken with VAED data have concluded that the data are reliable,<sup>27,30</sup> including

those that have previously examined adverse event coding.<sup>30-33</sup>

The standard of documentation in the medical record directly affects the adverse event rates and patterns reported for individual hospitals, and this is an inevitable limitation on the methods reported here. However, this is also the case for voluntary reporting of adverse events and for retrospective record review studies. Hospitals must ensure good coding beyond that required for DRG assignment. The usefulness of abstracted data for quality and safety purposes relies on good documentation in the medical record, thorough coding and periodic data audit.

The method described here was useful in determining patterns of adverse events and their frequency and rates. Because of the grouping levels for principal procedures and for C-prefixed diagnoses, “drilling down” from “coarse” to “fine-grained” data is possible. The C-prefix allows incident events to be distinguished from pre-existing injuries.<sup>26</sup> Hospitals should consider monitoring complication rates for individual elective procedures or blocks of similar procedures, and comparing adverse event rates over time and with peer hospitals as an integral part of their patient safety programs. Importantly, this method is based on accessing an extremely rich existing data source, making it a timely and economic means of record review.

Limitations of the method include the fact that hospitals differ in the resources devoted to record abstraction, resulting in variable coding depth.<sup>26</sup> Where codes lie outside the “external cause” ranges of the ICD-10-AM (that is, where the C-prefix flags non-specific adverse events), the “cause” of the complication is not readily apparent. Thus, urinary tract infections or pneumonias with a C-prefix will require further investigation as to explanatory factors such as prolonged catheterisation or delayed ambulation. The data are more helpful in identifying broad patterns of events and a sampling frame for further investigation, rather than as a tool to investigate what went wrong in individual cases. As with retrospective record review, it may be difficult to track patient complications after

discharge, and rates will be underestimated for this reason.

Depending on the research purpose, this method can be modified, for example, to investigate new procedures and their associated complications, or monitoring of hip and knee replacements for infection rates or other complications. Electronic health records should be developed with an awareness of adverse event recording and a prefix or other marker to indicate the timing of particular diagnoses, so that hospitals are able to manage their safety and quality programs effectively, and to benefit future research into adverse event prevention.

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## Competing interests

The authors declare that they have no competing interests.

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