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Appendix 1

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Appendix to: Sullivan C, Staib A, Khanna S, et al. The National Emergency Access Target (NEAT) and the 4-hour rule for emergency departments: time to review the target. *Med J Aust* 2016; 204: 354. doi: 10.5694/mja15.01177.

APPENDIX 1

Details of the eHSMR Modelling

Data Preparation:

Of the available 168 hospitals in the extract obtained from The Health Roundtable Ltd (HRT), 33 hospitals located in New Zealand were excluded as New Zealand has different targets. Of the remaining 135 Australian hospitals, 26 sites were excluded as no ED data was available for them in the extract. Another two sites were excluded as they represented specialist hospitals that are known to have a mortality profile very different to general hospitals (1). A further 48 sites were excluded as they had between 1 and 3 years of missing ED data in the extract. The remaining 59 sites were included in the analysis. Of these, 8 had between 1 and 9 days of missing ED data, possibly indicating no ED activity on the day. Inpatient activity was available for the entire study period for the included 59 hospital sites.

The study focused on calculating the hospital standardised mortality ratio (HSMR) for patients admitted via the emergency department, hereafter referred to as the emergency hospital standardised mortality ratio (eHSMR). Elective patients, patients coded as dead-on-arrival with a principal diagnosis of sudden unexplained death or who died in ED, organ donation episodes, non-acute and geriatric evaluation and management episodes, and all neonates were excluded. Palliative care patients were excluded from the primary analysis in accordance with other published work in the area of in-hospital mortality (1). Short stay inpatients (defined as inpatient LOS<24 hour regardless of inpatient destination), were excluded from the mortality analysis because of variability in the use of short stay unit and clinical decision units and inconsistencies in coding practices between hospitals. Multiple patient episodes representing the same stay in hospital were merged to ensure each episode represented a single stay in hospital. This ensured that statistical discharges resulting from change of caretype etc. did not affect the calculation of eHSMR.

In addition to the primary analysis patient cohort, two additional patient cohorts were created to analyse any potential bias introduced by including palliative care and short stay unit stays on the relationship between NEAT and eHSMR : 1.A cohort that represented the primary analysis patient cohort but included patients coded as palliative care at the time of death, 2. A cohort that represented the primary analysis patient cohort but included patients with short stays, defined as length of hospital stay (LOS) <24 hours which served as a proxy for those patients admitted to short stay observation wards or clinical decision units which overcame inconsistencies between hospitals in how transfers to such wards were coded as inpatient admissions and 3. A cohort including both patients coded as palliative care at the time of death and patients with short stays.

eHSMR Modelling :

Risk-adjusted regression models of in-hospital mortality resulting from ED admissions were used to calculate expected mortality for each hospital. This was then employed in calculating eHSMRs (see equation 1).

$$eHSMR = \frac{Actual\ number\ of\ in{-}hospital\ deaths\ among\ patients\ admitted\ through\ ED}{Expected\ number\ of\ in{-}hospital\ deaths\ among\ patients\ admitted\ through\ ED} \quad (1)$$

In keeping with established methodology for calculating standardised in-hospital mortality, we applied the approach advocated by Ben-Tovin (1) and developed models in two groups. The first 3 characters of the principal diagnosis (ICD10 code) were used to segregate the episodes into two groups - the first comprising 68 ICD10 codes that accounted for 80% of in-hospital deaths (see Table A.1), and the second comprising the rest of the ICD10 codes that accounted for the balance 20% of in-hospital deaths.

ICD code	Description	ICD code	Description
A41	Other sepsis	I50	Heart failure
C15	Malignant neoplasm of oesophagus	I60	Subarachnoid haemorrhage
C16	Malignant neoplasm of stomach	I61	Intracerebral haemorrhage
C18	Malignant neoplasm of colon	I62	Other nontraumatic intracranial haemorrhage
C20	Malignant neoplasm of rectum	I63	Cerebral infarction
C22	Malignant neoplasm of liver and intrahepatic bile ducts	I64	Stroke, not specified as haemorrhage or infarction
C25	Malignant neoplasm of pancreas	I70	Atherosclerosis
C34	Malignant neoplasm of bronchus and lung	I71	Aortic aneurysm and dissection
C45	Mesothelioma	J15	Bacterial pneumonia, not elsewhere classified
C50	Malignant neoplasm of breast	J18	Pneumonia, organism unspecified
C56	Malignant neoplasm of ovary	J22	Unspecified acute lower respiratory infection
C61	Malignant neoplasm of prostate	J44	Other chronic obstructive pulmonary disease
C64	Malignant neoplasm of kidney, except renal pelvis	J69	Pneumonitis due to solids and liquids
C67	Malignant neoplasm of bladder	J84	Other interstitial pulmonary diseases
C71	Malignant neoplasm of brain	J90	Pleural effusion, not elsewhere classified
C78	Secondary malignant neoplasm of respiratory and digestive organs	J96	Respiratory failure, not elsewhere classified
C79	Secondary malignant neoplasm of other sites	K52	Other noninfective gastroenteritis and colitis
C80	Malignant neoplasm without specification of site	K55	Vascular disorders of intestine
C83	Diffuse non-Hodgkin lymphoma	K56	Paralytic ileus and intestinal obstruction without hernia
C85	Other and unspecified types of non-Hodgkin lymphoma	K57	Diverticular disease of intestine
C90	Multiple myeloma and malignant plasma cell neoplasms	K63	Other diseases of intestine
C91	Lymphoid leukaemia	K70	Alcoholic liver disease
C92	Myeloid leukaemia	K72	Hepatic failure, not elsewhere classified
E11	Type 2 diabetes mellitus	K85	Acute pancreatitis
E86	Volume depletion	K92	Other diseases of digestive system

E87	Other disorders of fluid, electrolyte and acid-base balance	L03	Cellulitis
G93	Other disorders of brain	N17	Acute renal failure
I20	Angina pectoris	N18	Chronic renal failure
I21	Acute myocardial infarction	N39	Other disorders of urinary system
I25	Chronic ischaemic heart disease	R55	Syncope and collapse
I26	Pulmonary embolism	S06	Intracranial injury
I46	Cardiac arrest	S32	Fracture of lumbar spine and pelvis
I48	Atrial fibrillation and flutter	S72	Fracture of femur
I49	Other cardiac arrhythmias	T81	Complications of procedures, not elsewhere classified

Table A.1 : List of 68 Principal Diagnosis Codes representing highest frequency of in-hospital deaths[1]

Receiver Operating Characteristic (ROC) curve analysis was employed to measure the performance of the models, with the c-statistic (or AUC), representing the area under the ROC curve, used as a measure of discrimination and used to compare the performance of the models. Models were developed using 64-bit version of the R project for statistical computing on an Intel E5-2630 CPU machine with 2x2.6GHz processors and 128GB of RAM.

For calculating eHSMR, two methods of model selection were employed; namely, elastic net (2) and backwards stepwise variable selection. All models were a binary generalized linear model, with the response variable being whether or not a subject died or not coded as 1,0 respectively.

Elastic Net is a regularization and variable selection method for building generalised linear models when you have either many more predictors than data or you have some sparseness in your model matrix. To calculate the eHSMR is this study we looked at a number of variables and all two-way interactions between them. Ordinary stepwise regression techniques failed to converge due to small cell counts in some two-way interaction terms.

Initial models included the following variables and all their two-way interactions; DRG7 complexity score, Hospital ID, Length Of Stay (1,2,3,7,14,28,>28days), Gender, Admission Source, Number of Procedures (0,1,2,3,4,5,>5), Number of Diagnoses (0,1,2,3,4,5,>5), Charlson Comorbidity Index Group (0,1,2,3,4,5,>5), Age in Years, Age Squared, Age Cubed, Age Group (1,16,34,49,64,79,>79) and Hospital Type.

ICD codes from the low mortality ICD codes group were collapsed into ten groups using k-means clustering according to frequency of mortality for each ICD-10 code and included in all two-way interactions. The 68 ICD from the high mortality group were not included in two-way interactions, they were added as a main effect only.

Variable selection for the elastic net was done via 10 fold cross validation, with the penalty tuning parameter chosen as the lambda within one standard deviation of the minimum.

The above modelling was carried out for the principal patients cohort and then repeated for the palliative patients included cohort and short stay patients incuded cohort to obtain individual models for the high mortality and low mortality groups for each of the 3 cohorts.

References :

1. Ben-Tovim D, Woodman R, Harrison JE, et al. Measuring and reporting mortality in hospital patients. Canberra: AIHW, 2009.
2. T. Hastie, R. Tribshirani, and J. Friedman. The Elements of Statistical Learning: Data Mining, Inference, and Prediction. Springer, second edition, February 2009.