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Appendix: construction of the HSMR in England

Cleaning and processing

We apply Hospital Episode Statistics (HES) data cleaning rules to the Secondary Uses Service (SUS) records. Only ages within the ranges 1-120 and 7001-7007 (special values to indicate age in months for children under 1 year) are considered valid. Duplicate records (those with the same combination of provider, date of birth, sex, postcode, date of admission and episode number (PROCODE, DOB, SEX, HOMEADD, EPISTART, EPIEND, EPIORDER), unfinished episodes, those with missing/invalid ADMIDATE and regular attenders (CLASSPAT=3,4) are excluded. Some spells have the same date of admission (ADMIDATE) but different dates of discharge (DISDATE). This is not valid unless the patient was discharged and readmitted on the same day: if not, the spell with the earliest DISDATE was arbitrarily taken to be the valid one. Episodes relating to the invalid spell are excluded at this stage.

As hospitals merge and services reorganised, provider codes (PROCODE) may change from one year to the next. In order to track hospitals over time, the provider codes need to be unified, i.e. just one code needs to identify each trust throughout. To date, provider codes have been unified as of the trust status at April 2009.

Linkage

The data are in the form of consultant episodes (the continuous period during which the patient is under the care of one consultant), which need to be linked into admissions (or "spells"). Records are assumed to belong to the same person if they match on date of birth, sex and postcode (DOB, SEX, HOMEADD) as the NHS number is either not available or not recorded accurately enough across the whole period for which we have data. For the period from 2000/01 to 2005/06 we have used HESID as a patient identifier (we did not have this for earlier HES years). This links patients together based on either their NHS number (with other fields added) or their local patient identifier (with other fields added). A detailed algorithm on how the HESID was derived by the Department of Health is available on request from the NHS Information Centre.

Spells ending in transfer to another NHS hospital are linked together ("superspell"), allowing for a difference between discharge from the first trust and admission to the next trust of up to two days, using ADMIMETH= 81 or DISDEST/ADMISORC values of 49-53 (which refer to NHS providers). Spells with missing or negative length of stay are excluded from all analyses as for invalid age and sex.

Diagnosis derivation

We use the 56 diagnostic groups which contribute to 80% of in-hospital deaths in England. All 56 groups are listed in Table A1, and further information on the Clinical Classification System (including the ICD codes making up the groups) is available at http://www.ahrq.gov/data/hcup/icd10usrgd.htm.

For each spell we assign a diagnosis based on the primary diagnosis in the first episode of care. However, if the primary diagnosis is a vague symptom or sign we look to the subsequent episode (of a multi-episode spell) to derive a diagnosis.

Table A1. List of CCS groups used in English HSMRs together with their ROC c statistic for in-hospital mortality

CCS group	Description and C statistic for in-hospital mortality	
2	Septicemia (except in labour)	0.774
12	Cancer of oesophagus	0.813
13	Cancer of stomach	0.809
14	Cancer of colon	0.830
15	Cancer of rectum and anus	0.844
17	Cancer of pancreas	0.768
19	Cancer of bronchus, lung	0.779
24	Cancer of breast	0.935
27	Cancer of ovary	0.843
29	Cancer of prostate	0.859
32	Cancer of bladder	0.917
38	Non-Hodgkin's lymphoma	0.805
39	Leukaemias	0.814
42	Secondary malignancies	0.796
43	Malignant neoplasm without specification of site	0.800
55	Fluid and electrolyte disorders	0.766
59	Deficiency and other anaemia	0.755
68	Senility and organic mental disorders	0.664
100	Acute myocardial infarction	0.743
101	Coronary atherosclerosis and other heart disease	0.862
103	Pulmonary heart disease	0.778
106	Cardiac dysrhythmias	0.834
107	Cardiac arrest and ventricular fibrillation	0.702
108	Congestive heart failure, nonhypertensive	0.647
109	Acute cerebrovascular disease	0.705
114	Peripheral and visceral atherosclerosis	0.895
115	Aortic, peripheral, and visceral artery aneurysms	0.873
117	Other circulatory disease	0.853
122	Pneumonia (except that caused by tuberculosis or sexually transmitted disease)	0.800
125	Acute bronchitis	0.826
127	Chronic obstructive pulmonary disease and bronchiectasis	0.686
129	Aspiration pneumonitis, food/vomitus	0.716
130	Pleurisy, pneumothorax, pulmonary collapse	0.810
131	Respiratory failure, insufficiency, arrest (adult)	0.738
133	Other lower respiratory disease	0.873
134	Other upper respiratory disease	0.926
145	Intestinal obstruction without hernia	0.819
148	Peritonitis and intestinal abscess	0.868
149	Biliary tract disease	0.912
150	Liver disease, alcohol-related	0.700
151	Other liver diseases	0.850

153	Gastrointestinal haemorrhage	0.802
154	Noninfectious gastroenteritis	0.881
155	Other gastrointestinal disorders	0.895
157	Acute and unspecified renal failure	0.741
158	Chronic renal failure	0.873
159	Urinary tract infections	0.804
197	Skin and subcutaneous tissue infections	0.904
199	Chronic ulcer of skin	0.784
224	Other perinatal conditions	0.953
226	Fracture of neck of femur (hip)	0.743
231	Other fractures	0.804
233	Intracranial injury	0.753
237	Complication of device, implant or graft	0.809
245	Syncope	0.764
251	Abdominal pain	0.935

Model fitting

We define our death outcome when the patient dies in hospital at any time during their stay in hospital (superspell). The spell in which death occurs (DISMETH = 4 or 5) may be post-transfer, but deaths are assigned to all the trusts in the superspell. We exclude day cases (spells where CLASSPAT = 2 in first episode) from our risk models and where a trust has more than one spell in a superspell, we include only the first spell.

For each diagnosis group (CCS) we derive predicted probabilities for inpatient in-hospital mortality by fitting logistic regression models using SAS V9.1. We apply SAS's inbuilt backwards elimination procedure for variable selection, which starts with a model including all the selected explanatory variables and then automatically removes the variable with smallest F-statistic at each step until all the non-significant variables (using a cut-off of P>0.1) have been excluded.

We use the variables defined in Table A2 as our predictors. We recategorise four variables – age group, deprivation, comorbidity and number of previous admissions – depending on the absolute number of events, so that each category contains at least 20 events. Starting from the first (lowest) category, we combine it with the next lowest category if it contains fewer than 20 events and continue combining until that total has been reached. We then inspect the next highest category and repeat the process as necessary. If the last category is left with fewer than 20 events then it is combined with the second last category as one group. This is to assist with model convergence. We have also tried using 10 as a minimum rather than 20 and the coefficients rarely differed.

Day cases are given a predicted risk of zero, but any deaths occurring in day cases are included in the HSMR. Risk estimates for data in years after the last year included in the risk model (currently 2008/09) are calculated using the log odds value for the last year in the model.

The success of case-mix adjustment for accurately predicting the outcome (discrimination) was evaluated using the area under the receiver operating characteristic curve (c statistic) given in Table 3. The c statistic is the probability of assigning a greater risk of death to a randomly selected patient who died compared with a randomly selected patient who survived. A value of 0.5 suggests that the model is no better than random chance in predicting death. A value of 1.0 suggests perfect discrimination, though for some models the theoretical maximum may be less than this. In general, values less than 0.7 are considered to show poor discrimination, values of 0.7-0.8 can be described as reasonable and values above 0.8 suggest good discrimination. Models were also assessed by calibration plots and other measures such as McFadden's R-squared.

Table A2. Covariates used in risk-adjustment models used in each individual Clinical Classification System diagnosis group underlying the English HSMR in general order of importance.

Variable	Description	Details and issues
Age	Categorical: <1, 1-4, 5-9 then five-year bands up to 90+	Record excluded if invalid
Sex		Record excluded if invalid
CCS diagnosis subgroup	As for diagnosis group	
Year	Financial year	
Month of admission		To adjust for seasonal variations
Method of admission		Unplanned v other
Charlson index of comorbidity	Covers chronic conditions such as diabetes and dementia	Based on Australian ICD10 version. We have recently recalibrated for English data
Palliative care	0/1 flag	Based on ICD10 code Z515 or specialty of any episode in the admission
Number of unplanned admissions in previous year	0, 1, 2, 3+	Attempts to adjust for disease severity and differing admission thresholds
Source of admission	Where patient is admitted from, e.g. their own home, another hospital	Not always well coded
Ethnic group	Six groups	Around 15% missing in recent data (30% in earlier years)
Deprivation	Population-weighted quintiles of the Carstairs index at the small area level (output area)	Includes a sixth quintile for postcodes not matching to an output area

NB Only factors which are statistically significant ($p<0.1$) are included in models for each CCS diagnosis group