The impact of patient characteristics, hospital and ward resource levels on health outcomes over a ten year period

By

A. McGuire, M. Raikou and F. Windmeijer

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Introduction

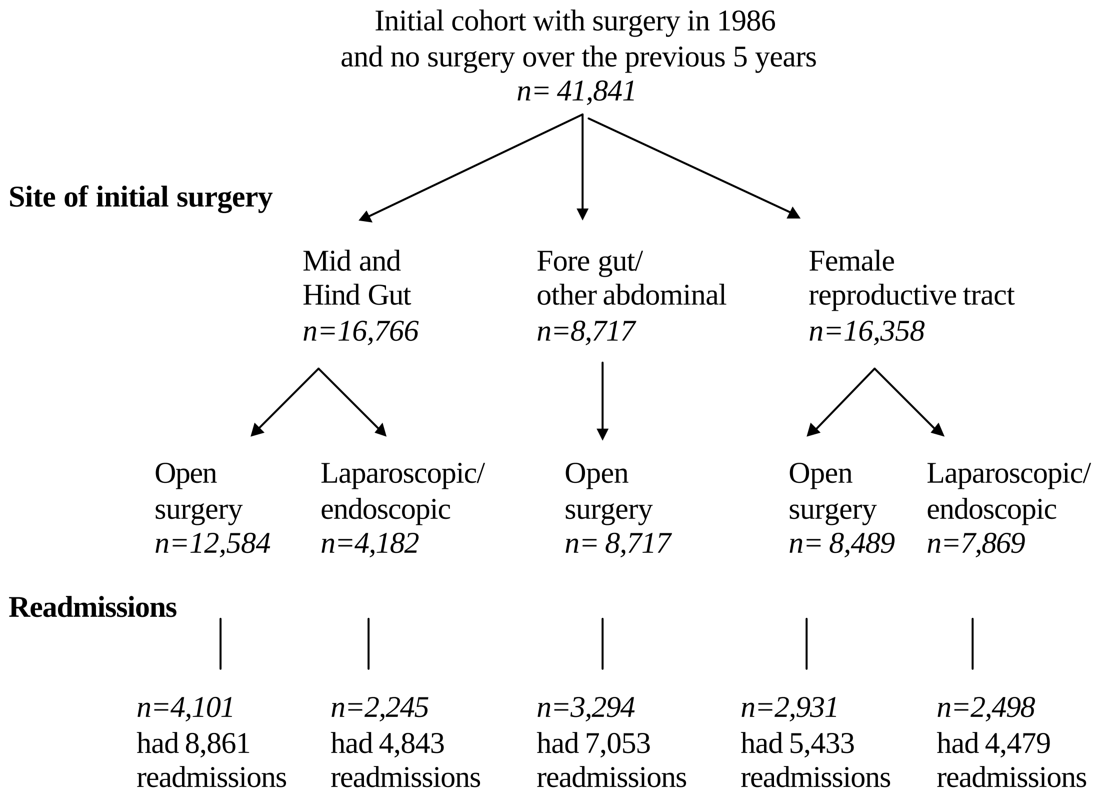
There is increasing interest in the relationship between resource patterns and health outcomes. While this has been studied extensively at an aggregate level, there have been few studies which have considered such relationships at the individual patient level. This largely reflects the lack of follow-up data which would allow such analysis. The aim of this paper is to present some information on long-term health outcomes relating to hospital re-admission and death following surgery. The analysis is based on hospital record linkage data which allows identification of patients who have had an incident surgical episode, defined as no surgery in a five year prior period, and tracks all hospital re-admissions for these individuals over a subsequent ten year period.

Methods

Data were retrieved from the Medical Record Linkage database held by the Information and Statistics Division (ISD) of the NHS in Scotland. This database holds linked data on all in-patient and day case hospital episodes from 1981 onwards within Scotland – excluding psychiatric and maternity admissions. This database has identified every individual within Scotland in 1986 who had been admitted for abdominal/pelvic surgery. This particular year was chosen to allow identification of an incident population, defined as individuals who had had no prior abdominal or pelvic surgery in the period 1981 to 1986. An incident population was identified of 41,841 individuals who were then followed over a ten year period and all subsequent hospital readmissions were recorded. Figure 1 describes the population in terms of their site of initial surgery and shows that 15,069 patients had at least one subsequent re-admission. The greatest number of re-admissions over the ten year period was 45, with 26,774 individuals having no re-admission. The frequency of re-admission, as shown in Figure 2 is highly skewed with 10,891 individuals having no more than two re-admissions over the ten year period and 14,909 individuals having 10 or less.

The recorded data also included length of stay, procedures performed, and discharge information. Admissions were based on OPCS-3 and OPCS-4 operative procedure codes as well as ICD-9 diagnostic codes. Three distinct categories of initial surgery were identified for analysis; surgery of the mid/hind gut, (which includes the rectum, colon, appendix, small intestine and abdominal wall); surgery of the fore gut and other abdominal organs (which includes the stomach, gall bladder, pancreas, kidney, bladder and hernias); and surgery of the female reproductive system. The data is also linked to mortality information.

Figure 1. Study population



The ISD Medical Record Linkage Database is detailed elsewhere. It has been subjected to a number of reviews relating to it's quality and ability to link hospital episodes.[2,3] The database has been found to have a high level of accuracy as assessed by an internal audit of one per cent of the hospital returns annually. The accuracy of the linkage system is around 99 per cent overall, while reviews of individual diagnostic categories and surgical procedures returns an accuracy of 90 per cent and 94 per cent respectively.[3] Moreover, the demographics of the Scottish population is advantageous as the population is stable and has low levels of annual migration.[4]

This patient individual hospital episode data was then matched through the hospital code to hospital resource information on bed levels, occupancy rates and staffing levels for the initial incident surgical event. Various expenditure data were also collected. This matching of data allowed testing of the hypothesis that hospital resource at the initial incident surgical event was predictive of subsequent health outcome measured by number of re-admissions and death. In matching the data 12,455 individual patient records were excluded as information on initial hospital resource was not available. The total number of linked individual patient records available for analyses was therefore 29,386.

Two forms of regression were run. The re-admission data are clear examples of count data and a negative binomial model was estimated. The negative binomial model is essentially a Poisson model allowing for over-dispertion. The Poisson regression model specifies that each occurrence, or count, (Y_i) is drawn from a Poission distribution defined by parameter λ_i which is functional related to a number of regressors x_i. If as log linear form is assumed this may be specified as:

Y_i = Poisson (μ_i)
where $\mu_i = \exp(x_i\beta + u_i)$
and e^{ui} ~gamma($1/\alpha$, $1/\alpha$) with α representing the overdispertion parameter.

The death variable is binary and a logit regression was run in this case of the form:
Prob (Y=1) = $e^{\beta' x} / 1 - e^{\beta' x} = \Lambda(\beta' x)$
Where the dependent variable records death as unity.

The independent regressors were similar in both cases. All relate either to individual patient characteristics (age, sex and whether open or laprascopic surgery was performed), or to hospital resource levels at the time of the initial incident surgical episode. These hospital resource variables were a mixture of throughput, expenditure and staffing aspects. Initial length of stay, which may be taken as a proxy for case severity, was recorded. At the hospital level to capture hospital effects the total running costs and the accident and emergency admissions for the incident year were recorded. Accident and emergency departments tend to be located in larger hospitals dealing with a more complex range of cases. At the ward level the occupancy rate within the surgical ward at the time of incident operation, the number of senior staff per one hundred weighted patients (with the weights relating to in-patients, out-patients and day cases), the number of trained nurses per one hundred weighted patients and the total number staff on the surgical ward were also recorded.

Results

The results are reported in Tables 1 through 4. Table 1 relates to the regression run on re-admissions, and Table 2 the estimated accompanying marginal effects. A likelihood ratio test for overdispertion supports the choice of the negative binomial model over the Poisson.

The signs on the variables indicate that increasing age, being female and initial incident length of stay, with the latter possibly reflecting individual case complexity, all increase the number of re-admissions. At the hospital level larger running costs and higher accident and emergency admissions do increase the number of re-admissions. These may reflect either institutional factors or that more complex cases are referred to larger hospitals and/or hospitals which are more specialised as proxied by the number of accident and emergency cases treated. However as the magnitude of the marginal effects on these hospital specific variables indicate their absolute impact on the number of re-admissions is negligible.

Most interestingly the ward level variables do suggest that hospital resources at this level do have an impact on the number of re-admissions. Lower absolute numbers of staff devoted to surgery and lower relative levels of senior medical staff devoted to surgery do appear to increase the predicted number of re-admissions. Higher claims on these surgical ward resources, as proxied by the ward occupancy level, also seems to increase the number of re-admissions. Perhaps surprisingly the higher the relative level of nursing the higher are the expected re-admissions.

Table 1 Negative Binomial regression results: dependent variable is number of re-admissions

Variable	**coefficient**	**s.e.**
Age at initial surgery	0.0059	0.0006361**
Sex	0.1380	0.0279317**
Nurse staff per 100 patients by surgical ward at initial surgery	0.0023	0.0008549**
Senior medical staff per 100 patients at initial surgery	-0.0063	0.0034881*
Length of stay at initial surgery	0.0071	0.0011878**
Total staff on surgical ward at initial surgery	-0.0004	0.0001736**
Open surgery	-0.1417	0.0296845**
Hospital running costs	0.000005	0.000002**
Accident and emergency admissions	0.000006	0.0000008**
Occupancy in surgical ward	0.0085	0.0021**
Constant	-1.5281	0.1656**

** Signifies significance at 5% level
* Signifies significance at 10% level
Number of obs = 29368
Log likelihood = -34783.602
Pseudo R2 = 0.0046

Table 2 marginal effects of the Negative binomial model

Variable	Marginal effects
Age at initial surgery	0.0046
Sex	0.108
Nurse staff per 100 patients by surgical ward at initial surgery	0.0018
Senior medical staff per 100 patients at initial surgery	-0.005
Length of stay at initial surgery	0.006
Total staff on surgical ward at initial surgery	-0.0003
Hospital running costs	0.000004
Accident and emergency admissions	0.000005
Occupancy in surgical ward	0.0066

Tables 3 and 4 give the results of the logistic regression relating deaths to the same patient, hospital and ward level data, with the non-significant variables having been dropped. Not surprisingly age has the largest impact. Being male is also highly significant. Initial surgical length of stay has a direct positive impact also. Open surgery is significant compared to laproscopic surgery, again this may be a proxy for greater case severity, given that laproscopic surgery was a relatively new technology in the mid-1980s. The lower the number of total surgical staff the greater is the probability of death. Once again the hospital level variables do have a significant impact but their absolute level of impact is very small.

Table 3: Logistic regression: death as dependent variable

Variable	**coefficient**	**s.e.**
Age at initial surgery	0.1018	0.0015**
Sex	-0.7596	0.0439**
Length of stay at initial surgery	0.0148	0.0017**
Total staff on surgical ward at initial surgery	-0.0004	0.0003*
Open surgery	0.437	0.0899**
Hospital running costs	0.000008	0.000003**
Accident and emergency admissions	0.000006	0.000001**
Constant	-6.24291	0.1428**

** Signifies significance at 5% level
* Signifies significance at 10% level
Number of obs = 29368
Log likelihood = -7542.6535
Pseudo R2 = 0.4653

Table 4 Marginal effects of logistic

Variable	**Marginal effects**
Age at initial surgery	0.0056
Sex	-0.042
Length of stay at initial surgery	0.0008
Total staff on surgical ward at initial surgery	-0.00002
Hospital running costs	0.0000004
Accident and emergency admissions	0.0000003

Conclusions

There does appear to be an impact on both re-admission levels and on the probability of death that can be traced back to initial hospitalisation resource levels. While the relative impacts of these effects are small, particularly at the hospital as compared to the ward level, they are significant. That these results occur even when considering subsequent deaths amongst our patient cohort. Given that these deaths could occur at any time within the ten year follow-up period this seems a particularly strong finding.