Quality of care and hospital resources: A study of hospital volume-outcome relationships

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Introduction

For obvious reasons there is increasing interest in the relationship between resource patterns and health outcomes with an emphasis on quality of care. In particular there have been a number of studies that have considered whether high surgical volume is related to improved quality of outcome (Luft et al, 1979; 1990). At the aggregate (hospital) level a positive volume-outcome relationship has been found. While some criticism of these findings exist, based on the lack of long-term follow-up data as well as a lack of case-mix and selective referral adjustment, it is generally believed that the aggregate conclusion is reflective of the positive correlation between volume and outcome that would be expected *a priori* at the individual surgeon level. Surgical provider confidentiality and the lack of suitable patient follow-up data are the main reasons why this particular research question has been studied extensively at an aggregate level, with few studies having considered such relationships at the individual patient level.

The aim of this paper is to pursue the volume-outcome relationship at the individual patient level using a database that provides extensive information on long-term health outcomes relating to hospital re-admission and death following surgery. The data relates to an incident population of individuals who have undergone surgery in 1986 and were subsequently followed-up for a ten-year period. 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. This data therefore controls for prior events, ensuring that any long-term volume-outcome relationship is truly defined, and allows extensive long-term follow-up.

Particular interest in this study focuses on a patient population who experience surgical adhesions after incident surgery. Surgical adhesions are known to be a common by-product of all types of major surgery. Adhesions are internal “scars” that form after trauma through complex processes, involving injured tissues and the peritoneum. Intestinal obstruction is the most severe consequence of adhesions and 30 to 40 per cent of patients who require abdominal re-operation have adhesion-related intestinal obstruction. The only major epidemiological study in this area found that a total of 36 per cent of the patients undergoing incident open abdominal or pelvic surgery were readmitted a mean of 2.1 times over a 10-year period for a disorder directly or possibly related to adhesions, with over half (53.8%) of patients readmitted at least once and 41% of patients having two to five admissions. Approximately 5 per cent of patients had six or more readmissions. It is not known precisely what causes adhesions arising from surgery, but it may be speculated that the patient outcomes relating to surgical adhesions are be related to the initial intervention (Ellis et al, 1999). They thus form a marker of quality of care.

The analysis undertaken below allows the outcome measures of interest, counts of hospital readmission (four separate groupings of one, two, three and four or more readmissions over a ten-year period for any individual patient) and mortality, to be correlated by estimating a competing risk duration model. A competing risk framework can be used in a manner that acknowledges that the outcomes being analysed are not independent. In this particular case it would be unreasonable to assume that the probability of a second or third hospital readmission was statistically independent of the first readmission for any given individual patient. If no account were taken of this correlation the underlying hazard rate being modelled would be underestimated. One way in which to model the correlation would be to apply a shared frailty model which would be used to measure within-group correlation, with the groups defined by restrictions imposed on the at risk population by the researcher. An alternative approach, adopted here, specifies that the baseline hazards for the competing risks be explicitly allowed to differ for different at risk groups through stratification and adjustment for correlation across the different strata then made through amendment to the variance-covariance matrix of the coefficients (Lin and Wei, 1989).

Data

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 inpatient and day case hospital episodes from 1981 onwards within Scotland – excluding psychiatric and maternity admissions. 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 (e.g. Kendrick and Clarke, 1993; Hartley and Jones, 1996). 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. Moreover, the demographics of the Scottish population is advantageous as the population is stable and has low levels of annual migration. Using this database every individual within Scotland in 1986 that had been admitted for abdominal/pelvic surgery was identified. This particular year was chosen to allow identification of an incident population, defined as individuals who had had no prior abdominal or female reproductive tract in the 5-years prior to the chosen date.

Once identified these patients were then followed up for a total of ten years. The recorded data included the patient's age and sex, 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. Surgery was also classified as open or laprascopic. The data is also linked to mortality information.

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 the vast majority of patients having had less than 5 re-admissions. In fact 26,772 had no re-admission over the period and 15,069 had 1 or more admission with, as noted above, 17,154 patients (41%) who had two to five readmissions.

Figure 1. Study population

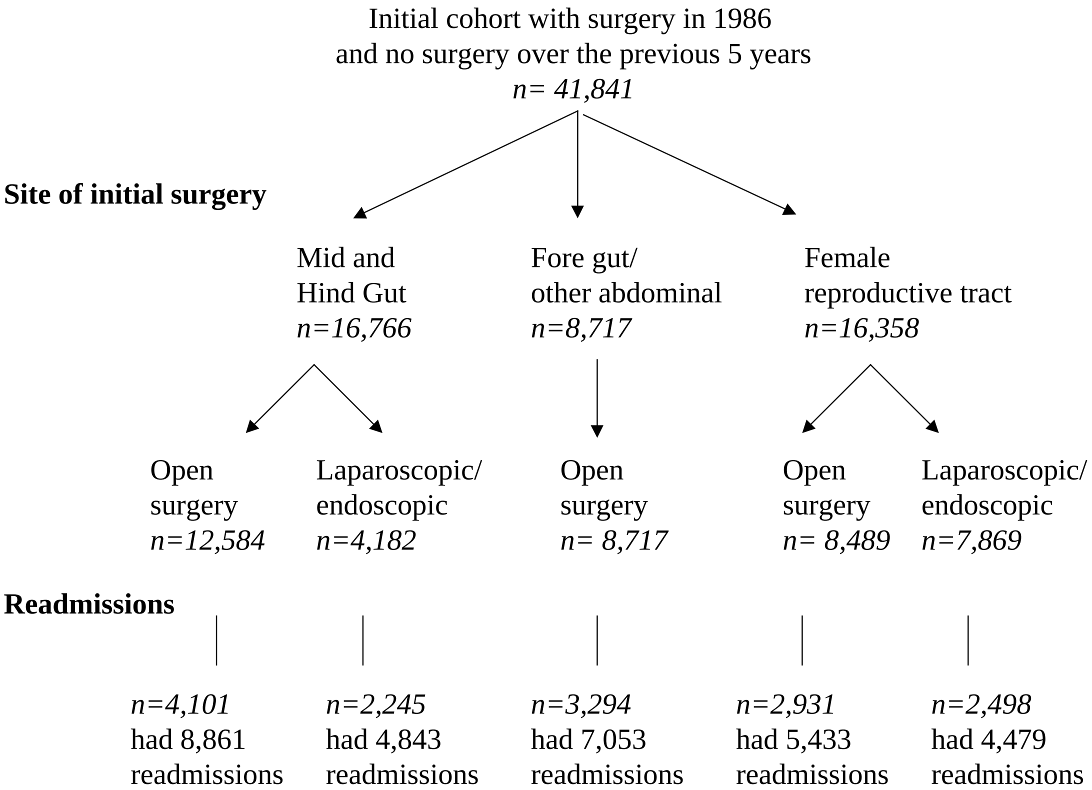
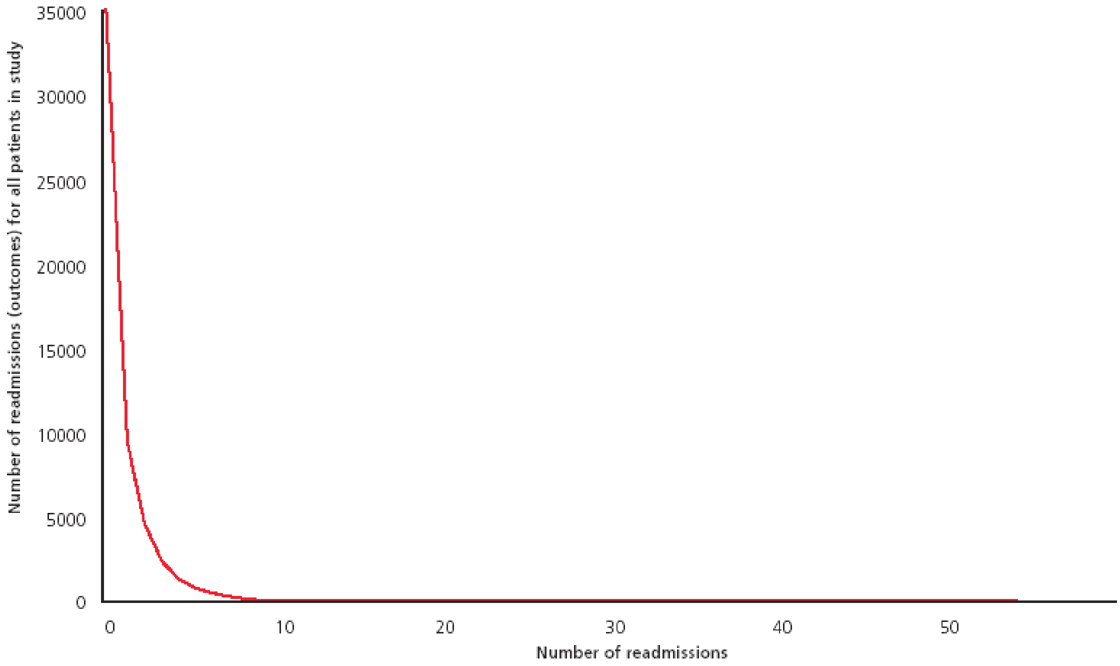


Figure 2. Number of readmissions (outcomes) for all patients in study



This data was then merged with data on Scottish hospital resource levels relating to the 1986, the year of the initial surgery. This data included hospital expenditure levels, total hospital admissions in the incident year of surgery (proxy for aggregate hospital volume of care), total patient admissions at the surgical ward level in the incident year of surgery (proxy for ward level volume of care), number of accident and emergency admissions (proxy for general severity of case-mix), average occupancy rates for the incident year on the surgical ward within the hospital (proxy for capacity utilization), senior medical staff per 100 patients on the surgical ward, nursing staff per 100 patients on the surgical ward.

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.

Methods

The competing risk model adopted here is a proportional hazards model based on the idea of marginal risk sets as proposed by Wei, Lin and Wessfeld (1989). Given *k* competing outcomes, for the *k*th type of failure for the *i*th subject, the hazard function $\lambda_{ki}(t)$ is assumed to take the form

$$\lambda_{ki}(t) = \lambda_{k0}(t)\exp\{\beta_k' Z_{ki}(t)\} \qquad t \geq 0$$

where $\lambda_{k0}(t)$ is an unspecified baseline hazard function and $\beta_k = (\beta_{1k},...,\beta_{pk})'$ is the failure specific regression parameter. Letting $R_k = \{l : X_{kl} \geq t\}$ be the set of subjects at risk just prior to the time *t* with respect to the *k*th failure type. Then the *k*th failure specific partial likelihood is given by

$$L_k(\beta) = \prod_{i=1}^{n}\left(\frac{\exp\{\beta' Z_{ki}(X_{ki})\}}{\sum_{l \in R_k(X_{ki})}\exp\{\beta' Z_{ki}(X_{ki})\}}\right)$$

The marginal risk set at time *t* for the event *k* consists of all the individual subjects under observation at time *t* who have not had an event *k*. The estimators $\hat{\beta}_k$'s are normally correlated. Lin and Wei (1989) propose a consistent variance-covariance estimator which allows for this correlation. The approach is general in that no specific structure of dependence is imposed among the distinct failure times of each individual subject. This allows greater generality than that imposed by shared frailty models while at the same time allowing for the potential correlation across outcomes.

This model was run using the up to five competing risks (one readmission, two readmissions, three readmissions, above four readmissions and death) and following covariates: age, sex, initial length of hospital stay, whether the initial surgical event was an open surgery, accident and emergency hospital admissions, occupancy rate on the surgical ward at time of admission, senior medical staff per 100 patients at time of initial admission, nursing staff per 100 patients at time of initial admission and teaching status of the hospital (for the ward level equation only). In additional the two variables of primary interest were the total hospital admissions in the incident year and the total surgical ward admissions in the primary year. Two separate regressions were run including one or other of these variables of primary interest.

Results

The results are reported below in Table 1. As can seen the results are encouraging. Most coefficients are significant at conventional levels. Positive coefficients indicate that an increase in the variable raises the probability of either a readmission or death. Thus the longer the initial length of stay and the higher the ward occupancy rate at the initial surgical event the higher the likelihood of a patient being readmitted over the 10-year follow-up period. This is consistent with the initial length of stay acting as a proxy for severity of condition at the initial event and occupancy rate acting as a proxy for resource constraints at the ward level at the time of initial surgical event. If the hospital was a teaching hospital the risk of subsequent readmission or death was diminished. The higher the level of hospital A&E admissions, taken as a marker of general patient severity levels as A&E departments are bigger in the bigger more complex hospitals, the higher the risk of readmission or death. Not surprisingly the older the patient was at the time of initial surgery the higher the probability of adverse outcome in the follow-up period, and if the patient was female there was also a higher risk of adverse outcome – possibly reflecting the slightly higher proportion of females in the initial population. Somewhat puzzlingly the higher the level of senior medical staff or nursing staff on the surgical ward at the time of initial surgical event the higher the probability of readmission or death.

Turning to the variables of interest, the total number of hospital admissions and the total number of surgical ward admissions at the initial surgical event, both are clearly significant at the 1 per cent level and indicate that as case volume increases at both the hospital and the ward level the likelihood of readmission or death in the subsequent 10-year follow-up period is diminished. Indeed, as expected, the effect is greatest at the ward level. From this study then it would appear that there is a significant volume-outcome effect.

Table 1. Competing risk models for the volume-outcome hypothesis

	Hospital level volume-output relationship		**Ward level volume-output relationship**	
Variable	Coefficient	Standard error	Coefficient	Standard error
Age	0.028*	0.0004	0.028**	0.0004
Sex	-0.194**	0.019	-0.194**	0.02
Initial length of stay	0.007**	0.0008	0.007**	0.0008
Open Surgery	-0.192**	0.0008	-0.194**	0.023
A&E admission levels in initial stay	0.000003**	0.00000004	0.000003**	0.0000006
Occupancy rate at initial stay	0.003	0.001	0.003	0.0016
Senior medical staff at initial stay	0.008**	0.002	0.008**	0.002
Nursing staff at initial stay	0.002**	0.0007	0.001*	0.0007
Teaching			-0.0482	0.025*
Total hospital admissions at initial event	-0.000005**	0.0000001		
Total ward level admissions at initial event			-0.0003**	0.00016
	N= 144,772 Log likelihood = -292117 # of failures= 28942		N= 144,772 Log likelihood = -292115 # of failures= 28942	

Discussion

This paper appears to substantiate the volume-output relationship found in the earlier literature using aggregate hospital data. It was shown that this effect holds both with hospital admissions taken as the volume proxy or the surgical ward admission taken as the level of cases treated. Indeed the lower level of aggregation gave the stronger effect. Given that any individual hospital surgical ward would not be expected to have more than four senior surgeons employed at any given time this is not surprising.

The richness of the data set employed has allowed a comprehensive examination of the volume-outcome hypothesis. The dataset allowed a clean out period to be specified thus enhancing the probability that only incident surgical cases were considered. Moreover the length of follow-up period has meant that long-term outcomes can be defined. This has clearly lends more support to the findings.

The model used to establish this finding stratifies the competing risk dataset treating each failure occurrence as belonging to an independent stratum. This allows for correlation across the differing competing outcomes of readmission and death. This modelling approach is perhaps an advantage over the alternative of specifying the type of frailty that would have to be imposed otherwise. An obvious extension of the paper however is to consider a shared frailty model. Hamilton and Hamilton (1997) and Picone et al (in press) both consider this alternative with a competing risk framework, and it is hoped that at a later stage this study will provide a contrast of the two methods.

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