Is there a cost quality trade-off in the provision of vascular services?

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Paper presented at the 70th Health Economics Study Group

Birmingham

3-5 January 2007

Work-in-progress

Acknowledgements

Funding for this work was provided by a fund under the Danish Pharmaceutical Association. We acknowledge the Danish Vascular Registry and the National Board of Health for provision of data. Thanks to all the participating Vascular Departments and in particular consultant and chairman of the Danish Vascular Registry Leif Panduro for help with both the provision, the validation and interpretation of data as well as comments along the way about (some of) the methods used. Any errors are the authors' responsibility

Abstract

Background: In Denmark costs for hospital treatment for vascular patient as well as clinical quality indicators are registered at an individual level in the National Cost Registry and the Danish Vascular Registry. In this study we explore how data can be best exploited to provide relevant information to the policy makers at the hospital department level about cost efficiency and patient outcomes.

Objectives: We examine both whether there is a cost quality trade-off in the performance of Danish vascular hospital departments, and whether differences among departments are due to departmental effort or to the characteristics of the patients treated. We have patient-level costs and outcomes are measured as 30-day mortality and wound infections. In addition to standard patient characteristics, such as gender, age and diagnosis, we are able to exploit a rich data set containing details about previous diseases, co-morbidities, and smoking status.

Methods: We estimate hierarchical models, in which 4,433 patients are clustered within 7 Danish vascular departments. To assess differences in outcomes between departments we estimate fixed and random effects models for the two outcome variables, applying a logit specification. By using the predicted outcomes from these models in a two stage least square (2SLS) model we further examines the correlation between costs and quality.

Results: First of all we found that differences between departments mortality is heavily reduced when controlling for patient characteristics. This does not hold for wound infections. Second of all we found that both mortality and wound infections are positively correlated with costs. Higher quality (lower mortality and lower degree of wound infections) is hence obtainable at lower costs.

Conclusions: This is work-in-progress and we would welcome guidance and comment at the HESG meeting. We are in particular interested in help and comments on the application of 2SLS in the cost-quality equations.

1. Introduction

It is received wisdom that quality is costly. But in the commercial sector, investing in quality is often also profitable because people are prepared to pay more for higher quality products, even for everyday items such as groceries. This is exemplified by the recent divergent fortunes of UK supermarkets in their battle for customers. The Wal-Mart owned Asda chain has been touting "everyday low prices" in its advertising campaigns, but has lost market share to Tesco, Sainsbury's and Waitrose, that have been promoting the quality of their products and charging more for premium brands (1). Investing in quality makes business sense if people are prepared to pay a premium for what is perceived to be a higher quality product.

But the same reasoning is not easily transferable to the health sector, where consumers do not pay (fully) for health care services and negotiated prices between third-party payers and providers are rarely differentiated on the basis of quality. If quality has a positive impact on costs but does not affect revenue, providers will under-invest in quality, with services meeting only minimum (regulated) standards and no differentiation among providers on the basis of quality. But this behaviour may not be observed in practice if there is not a straightforward relationship between costs and quality.

It is challenging to examine nature of the cost-quality relationship because quality is difficult to define and measure, most particularly because it is multi-dimensional. Some dimensions of quality have a more obvious positive relationship to costs than others, notably those that are related to the process of health care delivery. Clearly it is more expensive to house patients in single rooms than on shared wards. It is more costly to offer elective patients shorter waiting times before hospital admission, because hospitals will have to hold more stand-by capacity in order to maintain access for emergency patients.

It is less obvious that there is a positive relationship between costs and the outcomes of health care. Are patients who die in hospital more costly to care for than those who recover? Are the costs of ensuring good infection control offset by lower costs arising from fewer wound or MRSA infections? Empirical analysis of questions such as these is usually hindered by lack of data, partly because few measures of health outcome are collected routinely and, for those that are, they tend to be reported at aggregated levels, such as for the hospital as a whole. Aggregation limits the inferences that can be drawn, if only because it is more difficult to make precise linkages between variables of interest (e.g. between hospital-level costs and the mortality rate).

In this paper, we exploit a rich patient-level data set that contains details of the diagnostic characteristics, costs and clinical outcomes of patients treated in seven (out of eight) vascular departments in Denmark in 2004. A paper by Olsen and Street (2006) (2) on the same set of cost data as in the present study has demonstrated that efficiency differs between the vascular departments. The construction of confidence intervals allowed the 7 vascular departments to be sorted into three groups: significantly more efficient departments; significantly less efficient departments; and departments that fell between these extremes. In the present paper we extend this analysis by considering differences in the outcomes experienced by patients, and by exploring the relationship between costs and these outcomes (in other words, to assess whether there is a cost quality trade-off). The present study has four main purposes. First, we evaluate 30-day mortality and wound infection among departments and assess the extent to which differences are due to patient characteristics. Second, we compare partial risk-adjustment models that take age, gender and case-mix into account with a broader set of risk-adjustment factors not traditionally available to researchers, including the presence of co-morbidities, smoking status and American Society of Anesthesiogists (ASA) score. Third, we assess the relationship between the costs of treating individual patients and the quality of their care, measured by their survival status and whether or not they suffered wound infection. Finally, we evaluate relative departmental performance in relation to the costs incurred and the outcomes achieved under different performance dimensions and various model specifications.

2. Data and descriptive statistics

Data were available for 4,433 patients treated in seven (out of eight) vascular departments in Denmark in 2004. The cost data were taken from the National Cost database and cover the resources used during admission for intensive care, laboratory tests, procedures, ward stays etc. The National Cost Database is based on patient-level data reported by each hospital according to accounting guidelines set out by the National Board of Health and, for ancillary services, by applying a national set of relative service weights. Although subject to national guidance, there may be differences among hospitals in the way they apportion fixed or overhead costs, and this may explain some of the variation across departments in the patient-level costs they report. The National Cost Database is the basis of the Danish case-mix system DkDRG, under which hospitals are reimbursed.

Data on patient characteristics are drawn from The Danish Vascular Registry, which is a national (clinical) registry for quality measures for all vascular hospital departments in Denmark (3). The Danish Vascular Registry was established by the Danish Vascular Society and contains information on patient specific characteristics such as age, gender, smoking status, disease status (including previous diseases) and surgical information. The main purpose of the Danish Vascular Registry is to monitor quality of care, the main quality indicators being 30-day mortality and wound infections.

The probability of dying within 30 days and of having a wound infection will be related to the specific characteristics of each patient. Traditionally, risk-adjustment is able to take account of only a limited set of patient characteristics, such as age, gender and case-mix. Casemix is defined according to the DRG to which each patient is allocated, with DRG-weights corresponding to the reimbursement rate, and the adjustment for case mix is the DRG-weight for the individual patient divided by the average DRG-weight for all patients. The Registry allows us to perform enhanced risk adjustment, by including additional patient characteristics including previous and present diseases, acute or elective status, and smoker history. The former set of variables are listed as vector $\mathbf{x}_1$ in table 1, while the additional variables are listed as vector $\mathbf{x}_2$. Descriptive statistics for the sample as a whole are provided in table 2.

Table 1: The Danish Vascular Registry: selected variables

	Variable	Description
Basic patient characteristics		
$\mathbf{x}_1$	Sex (Male)	Dummy of 1 if the patient is male
	Age	Continuous variable
	Case-mix	DRG-weihgt for the individual patient divided by the average DRG-weight for all patients (continuos variable)
Additional patient characteristics		
$\mathbf{x}_2$	Home care	Dummy of 1 if the patient requires home care
	Smoker	Dummy of 1 if the patient is smoker or ex-smoker
	Diabetes	Dummy of 1 if patient has type 2 diabetes
	Cerebrovascular	Dummy of 1 if the patient has been treated for TIA/amaurosis or stroke
	Hypertension	Dummy of 1 if the patient has hypertension
	Cardial	Dummy of 1 if the patient has been treated for cardiac disease
	Pulmonal	Dummy of 1 if the patient has been treated for pulmonary disease
	ASA score	Categoric variable (1-5) of the severity of the patient's condition. 1 is normal health condition and 5 is expected death within 24 hours without treatment.
	Intensive	Dummy of 1 of the patient is treated in intensive care for more than 3 days
	Acute	Dummy of 1 if the patient is acute (emergency)

Table 2: Descriptive statistics

Variable	Mean	Std.	Min	Max
Costs (DKK)	64,571	58,902	2,244	733,644
Expected costs (DKK)	63,576	60,667	1,393	754,015
Number of patients*	619	-	426	985
Casemix index	1	0.95	0.02	11.86
Age	67	13.16	4	98
Male	0.58	0.49	0	1
Smoker	0.74	0.44	0	1
Acute	0.35	0.48	0	1
Home care	0.19	0.39	0	1
Cerebrovascular	0.15	0.36	0	1
Hypertension	0.48	0.50	0	1
Cardial	0.31	0.46	0	1
Pulmonal	0.14	0.34	0	1
Diabetes	0.27	0.64	0	2
ASA score	2.07	0.75	1	5
Intensive	0.07	0.26	0	1

*in the individual departments. Total number of patients is 4,333

Table 3 presents data on the costs and outcomes experienced by patients according to the vascular department where they were treated. There appear to be clear differences among departments. For example, department F reports the lowest cost per patient, and also has the lowest rate of wound infection and a low rate of mortality. Costs appear to be higher in departments with higher rates of wound infection, but the relationship between costs and the mortality rate does not appear straightforward. These descriptive data beg two questions. First, can the apparent differences among departments be explained by differences in the characteristics of the patients treated or are they indicative of differences in departmental performance? Second, what is the nature of the relationship between costs and the two measures of outcome?

Table 3: Costs and outcomes, by department

Depart-ment	N	Mean cost (DKK)	Rank (costs)	Bed days (mean)	Mortality (N)	Mortality (%)	Wound inf (N)		Wound inf (%)	
							0	1	0	1
A	503	98,262	7	5.5	34	6.8	482	16	96.79	3.21
B	426	63,202	4	8.0	11	2.5	419	6	98.59	1.41
C	985	63,362	5	6.0	69	7.0	946	31	96.83	3.17
D	566	69,449	6	7.1	24	4.2	537	24	95.72	4.28
E	751	61,045	3	6.9	51	6.8	733	16	97.86	2.14
F	462	44,608	1	5.9	14	3.0	454	6	98.70	1.30
G	740	56,378	2	6.5	58	7.8	721	18	97.56	2.44
Total	4,433	64,571			261	5.9	4,292	117	97.35	2.65

3. Methods

3.1 Analysis of mortality and wound infections

We estimate a series of logistic regression models to explain the probability of dying within 30-days (k=1) or the probability of suffering wound infection (k=2). Our initial model takes the form:

$$y_{ki} = \boldsymbol{\beta}\mathbf{x}_{1i} + \boldsymbol{\lambda}\mathbf{d}_i + \varepsilon_i, \qquad k = 1, 2 \qquad (1)$$

where y_k is the outcome measure, which takes the value of 1 if the patient *i* died (for y_1) or suffered a wound infection (for y_2), $\mathbf{x}_1$ is the vector of 'traditional' risk adjustment factors, and $\mathbf{d}$ is a vector of dummy variables for each department (the constant being suppressed). Our second model includes the additional risk-adjustment factors, vector $\mathbf{x}_2$:

$$y_{ki} = \boldsymbol{\beta}_1\mathbf{x}_{1i} + \boldsymbol{\beta}_2\mathbf{x}_{2i} + \boldsymbol{\lambda}\mathbf{d}_i + \varepsilon_i, \qquad k = 1,2 \tag{2}$$

This is equivalent to a fixed effects panel model. For comparison purposes, we also estimate a random effects model, specified as:

$$y_{kij} = \alpha + \boldsymbol{\beta}_1\mathbf{x}_{1ij} + \boldsymbol{\beta}_2\mathbf{x}_{2ij} + u_j + v_{ij}, \qquad k = 1,2 \tag{3}$$

where y_{1ij} takes a value of 1 if patient *i* died in department *j*. v_{ij} is the normal residual assumed to be *iid* with zero mean and constant variance; and u_j is the departmental effect. The intra-class correlation coefficient, ICC, is used to assess the proportion of the total variance attributable to the vascular departments, and is calculated as;

$$ICC_{ML} = \sigma^2_{uj}(\sigma^2_{uj} + \sigma^2_{vj})^{-1}, \qquad 0 < ICC < 1 \tag{4}$$

A larger value of ICC indicates a greater influence of the vascular department on the outcome measure of interest (4-5).

3.2 Analysis of costs and quality

We specify a series of models to explore the relationship between patient costs and outcome. The first is an 'unconditional' panel data model, estimated by both fixed and random effects:

$$c_{ij} = \alpha + \delta_1 y_{1ij} + \delta_2 y_{2ij} + u_j + v_{ij} \tag{5}$$

where c_{ij} is the cost of patient i in department j; y_{1ij} is a dummy variable measuring whether or not the patient died and y_{2ij} is a dummy variable measuring whether or not they suffered a wound infection. Here any systematic differences among departments in terms of the type of patients they treat will be captured by the department effect u_j. As such, it would be inappropriate to interpret this effect solely as a reflection of the effort departments exert in controlling costs.

It is not appropriate to use mortality and wound infections as parameters of quality without taking into account the severity of illness of the patients. Patients with more severe indications will all else equal have a larger probability of dying and some patients will have a higher risk of wound infections than other. This observation leads us to expect that the explanatory variables in (5) is subject to measurement error. As Carey and Burgess (6) we therefore use a 2SLS error-in-variables model as the estimation procedure using $\mathbf{x}_2$ as instruments for mortality and wound infections. In the first stage, fitted values for mortality $\hat{y}_{1ij}$ and wound infection $\hat{y}_{2ij}$ are obtained from equation (3) and, in the second stage, included in the cost equation:

$$c_{ij} = \alpha + \delta_1 \hat{y}_{1ij} + \delta_2 \hat{y}_{2ij} + u_j + v_{ij} \qquad (6)$$

4. Results

Results for the different model for 30 day mortality are presented in table 4. Gender and case-mix are significant predictors of death in all models. The FE and RE models differ in terms of which variables are significant, with the FE model attaching greater weight to age, and the RE model to the presence of cardiac and pulmonary conditions. The significant Hausman test favours the FE model because of correlation between the regressors and department effects. The departmental effects are not strong predictors of whether or not a patient died but are influential nevertheless –

35% of the variation in mortality is attributed to the department (rho=0.35). As exhibited in table 5, the departmental effects vary between the departments. When adjusting for the routine variables (x_1) we find significant differences in the departmental effects in ten cases. However, when adjusting for the additional variables as well ($x_1 + x_2$) we find significant differences in the departmental effect between department F and department C, E and F only.

Table 4: Mortality (bold if significant)

	Model 1 (x1)	Model 2 (x1+x2) (ML FE)	Model 3 (ML RE)
	Odds ratio (SE)	Odds ratio (SE)	Odds ratio (SE)
Male	1.06 (0.007)	1.04 (0.008)	0.97 (0.0036)
Age	1.43 (0.210)	1.52 (0.250)	1.09 (0.1559)
Case-mix	1.36 (0.587)	0.08 (0.076)	1.28 (0.0732)
Cerebral	-	0.96 (0.197)	0.93 (0.1822)
Hypertension	-	1.19 (0.184)	1.19 (0.1730)
Cardiac	-	1.15 (0.186)	1.63 (0.2461)
Pulmonal	-	1.34 (0.241)	1.56 (0.2658)
Diabetes	-	0.65 (0.090)	0.59 (0.8191)
Smoker	-	1.41 (0.266)	0.74 (0.1115)
Acute	-	2.91 (0.495)	2.59 (0.3909)
Home care	-	1.56 (0.274)	2.25 (0.3682)
Asa-score	-	2.52 (0.285)	1.54 (0.1440)
Intensive> 3 days	-	1.31 (0.362)	1.28 (0.3186)
DC*	0.0008 (0.0004)	0.00006 (0.00004)	-
DE	0.0006 (0.0003)	0.00008 (0.00006)	-
DB	0.0003 (0.0002)	0.00004 (0.00003)	-
DG	0.0006 (0.0003)	0.00008 (0.00005)	-
DD	0.0004 (0.0002)	0.00005 (0.00004)	-
DF	0.0003 (0.0002)	0.00004 (0.00003)	-
DA	0.0006 (0.0003)	0.00008 (0.00006)	-
R2	-	-	-
Log likelihood	-977.29	-661.47	-661.47
Hausman test	-	0.0000	0.0000
Sigma-u	-	1.32	1.32
Rho*	-	0.35	0.35

*Dummy for department C
**Departmental effect

Table 5: Mortality, differences in departmental effects (only significant differences, 5%)

Adjusted for x_1	Adjusted for $x_1 + x_2$
C and B	-
C and D	-
C and F	C and F
E and B	-
E and F	E and F
B and G	-
B and A	-
G and D	-
G and F	G and F
F and A	-

Note: The differences in departmental effects are only included in this table if they are significant at 5%

In table 6 the results for the different models for wound infections are presented. The estimated relationships between wound infection and the explanatory variables are sensitive to model specification. Patients who suffer diabetes are more likely to suffer wound infection, as are patients who are admitted as emergencies or who spend more than three days in intensive care. Again the FE model is preferred to the RE model. 83% of the variation in wound infections is attributed to the departmental level (rho=0.83). When adjusting for the routine variables (x_1) we find significant differences in the departmental effects in ten cases, mainly department C, D and other departments (see table 7). However, when adjusting for the additional variables as well ($x_1 + x_2$) we find significant differences in 4 cases only, mainly between department D and four other departments.

Table 6: Wound infections (bold if significant)

	Model 1 (x1)	Model 2 (x1+x2) (Ml FE)	Model 3 (ML RE)
	Odds ratio (SE)	Odds ratio (SE)	Odds ratio (SE)
Male	1.46 (0.2727)	1.27 (0.2518)	1.09 (0.1993)
Age	1.00 (0.0067)	1.00 (0.0072)	0.97 (0.0044)
Case-mix	1.20 (0.6740)	0.94 (0.0750)	0.96 (0.0749)
Cerebral	-	0.66 (0.2019)	0.69 (0.2100)
Hypertension	-	0.86 (0.1684)	0.87 (0.1686)
Cardiac	-	1.38 (0.2853)	1.65 (0.3346)
Pulmonal	-	0.97 (0.2528)	1.12 (0.2853)
Diabetes	-	1.58 (0.1883)	1.56 (0.1860)
Smoker	-	1.05 (0.2260)	0.83 (0.1582)
Acute	-	2.87 (0.5836)	2.47 (0.4654)
Home care	-	0.91 (0.2297)	1.11 (0.2733)
Asa-score	-	1.12 (0.1526)	0.85 (0.1054)
Intensive> 3 days	-	3.75 (0.9455)	3.33 (0.8210)
DC	0.03 (0.0146)	0.01 (0.0080)	-
DE	0.17 (0.0091)	0.01 (0.0049)	-
DB	0.12 (0.0072)	0.01 (0.0053)	-
DG	0.17 (0.0092)	0.01 (0.0054)	-
DD	0.37 (0.0184)	0.02 (0.0122)	-
DF	0.01 (0.0078)	0.01 (0.0062)	-
DA	0.03 (0.0161)	0.02 (0.0089)	-
R2	-	-	-
Log likelihood	-608.35	-509.11	-555.81
Hausmann test	-	0.0000	0.0000
Sigma	-	4.07	4.07
Rho*	-	0.83	0.83

*Departmental effect

Table 7: Wound infections, differences in departmental effects (only significant differences, 5%)

Adjusted for x_1	Adjusted for $x_1 + x_2$
C and E	-
C and B	-
C and G	-
C and F	-
E and D	E and D
B and D	B and D
B and A	-
G and D	G and D
D and F	D and F
F and A	-

Note: The differences in departmental effects are only included in this table if they are significant at 5%

In table 8 the results from the four cost models are presented; First, the cost models (FE and RE) with observed and actual outcome (model 1 and 2). Second, the results of the 2SLS cost models with predicted outcome values (model 3 and 4). The coefficients for deaths within 30 days (mort_30) and wound infections (wound_inf) from estimating equation 5 under FE and RE specifications are positive and significant, suggesting that patients who die or suffer wound infections are more costly to care for. Models 3 and 4 include the predicted mortality (mort_hat) and predicted wound infection (wound_hat), with these predictions derived from equation 2, where various risk factors are taken into account when explaining observed death or wound infection. There influence of death or wound infection on costs becomes stronger.

Table 8: Cost quality trade off (bold if significant)

	Model 1: Actual values, FE	Model 2: Actual values, RE	Model 3:2SLS, FE	Model 4: 2SLS, RE
	Coeff. (SE)	Coeff. (SE)	Coeff. (SE)	Coeff. (SE)
Cons	10.72 (0.1296)	10.74 (0.1105)	10.60 (0.1709)	10.62
Mort_30	0.15 (0.0528)	0.15 (0.0528)	-	-
Wound_inf	0.29 (0.0708)	0.29 (0.0708)	-	-
Mort_hat	-	-	1.65 (0.1521)	1.64 (0.1520)
Wound_hat	-	-	1.74 (0.3769)	1.76 (0.3766)
Sigma_u	0.27	0.29	0.27	0.28
Sigma_e	0.83	0.82	0.80	0.80
Rho*	0.10	0.11	0.10	0.11
Hausmann	0.8253	0.8253	0.5756	0.5756

Table 8 show that between 10 and 11% (rho=0.10-0.11) of the variation in costs is explained by departmental factors meaning that 89-90% is explained by individual factors. There are significant differences in departmental effect (the coefficients on the department dummies) between the departments as exhibited in table 9. These differences are present both after adjusting for x_1 (routine variables) and $x_1 + x_2$ (routine and additional variables) suggesting we do not gain any information about departmental effects (in relation to costs) when extending the risk adjustment from x_1 to $x_1 + x_2$.

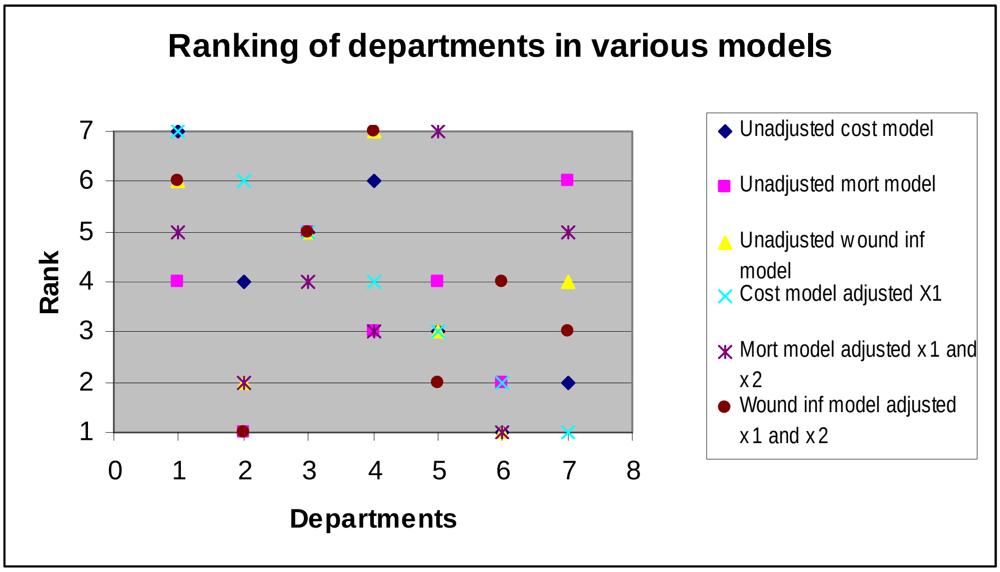
Table 9: Costs, differences in departmental effects (only significant differences, 5%)

Adjusted for x_1	Adjusted for $x_1 + x_2$
C and E	C and E
C and G	C and G
C and F	C and F
C and A	C and A
E and B	E and B
E and G	E and G
E and D	E and D
E and A	E and A
B and G	B and G
B and D	B and D
B and F	B and F
B and A	B and A
G and D	G and D
-	G and F
G and A	G and A
D and F	D and F
D and A	D and A
F and A	F and A

Note: The differences in departmental effects are only included in this table if they are significant at 5%

In figure 1 we have evaluated the departments' relative performance in relation to costs, 30 day mortality and wound infections under various model specifications. As figure 1 exhibit, the ranking from 1 to 7 (1 is best and 7 is worst) of the departments changes in the different models. In the unadjusted cost model (results depicted in table 3) department F is ranked as best (i.e. with the value 1) because of lowest costs. However, in the cost model adjusted for the routine variables (age, gender and case-mix) department G is ranked as the best with lowest costs (this model is not reported in this paper). In the unadjusted mortality model department B is ranked as the best (i.e. with the value 1) (results are shown in table 3). In the mortality model adjusted for both the routine and a number of additional variables department F is ranked as the best whereas department B now is ranked as second best. The matter of whether the differences are significant is not considered in figure 1 (but in tables 5, 7 and 9).

Figure 1: Ranking of departments from 1 to 7 under various models (1 is best)



Notice: Department A=1, B=2, C=3, D=4, E=5, F=6 and G=7.
The adjusted cost, mortality and wound infection models are ranked according to the departmental effect (the coefficients in the departmental dummies)

4. Discussion

In this paper we have used patient level data from seven vascular departments to analyse four issues. First, we have evaluated mortality and wound infection among departments and assessed the extent to which differences are due to patient characteristics. We find that approximately 65% and 13% of the variation in the 30 day mortality and wound infections respectively are explained by patient characteristics and the departmental effect is 35% and 87%. Also we find that the risk of death or wound infection varies by departments after controlling for the characteristics of patients admitted. For costs we find that approximately 90% of the variation is due to patient characteristics and the departmental effect is 10%.

Second, we compare models that take age, gender and case-mix into account with models that include a broader set of risk-adjustment factors. These additional risk factors add explanatory power and change the size and (sometimes) significance of the estimated influence of the more standard risk adjustment factors. However, few of these additional factors are individually significant, particularly under the favoured FE specification. Patients with diabetes or patients who are admitted as emergencies are more likely to die within 30-days or to suffer wound infection. Mortality is also higher for patients who require home care and those with higher ASA scores and infections are more common among patients who spend time in intensive care. This suggests that it is important to take account of these characteristics when the comparing the outcomes experienced by patients in different vascular departments, but that other characteristics are of lesser concern. Including these additional explanatory variables reduce the significance of difference between departments when it comes to mortality whereas the differences remain in case of wound infections. This result indicates that wound infection may be due to differences in treatment quality in the departments.

Third, we assessed the relationship between the costs of treating individual patients and the quality of their care, measured by their survival status and whether or not they suffered wound infection. We find that costs are higher for patients who die within 30-days of their admission and for those that suffer wound infection. This holds irrespective of whether we estimate the relationship between cost and outcome using observed outcomes or predicted values (2SLS), after taking account of risk factors. This implies that attempts to improve quality that lead to lower rates of mortality and wound infection would lead to lower costs, which contrasts with received wisdom that higher quality is more costly.

Finally, we evaluated the relative departmental performance in relation to the costs incurred and the outcomes achieved under different performance dimensions and various model specifications (figure 1). We find different results for the various models indicating that there are a number of dimensions to include when assessing the performance of department and no single outcome or costs should be used in ranking of hospitals or departments. However, department F comes out as number one (or two) in most models.

We recognise a number of deficiencies in the current study, some of which may be addressed by further refinement of the analysis, but others of which reflect limitations with our dataset. Our dataset is rich, being based on patient-level observations, containing a number of variables that are not typically available to researchers, and measuring outcomes that are judged to be clinically important. Even so, these outcomes (fortunately!) affect only a small proportion of vascular patients. Outcome information on others is unavailable, and there may be important differences among departments in the quality of care that these patients receive. However, it is not possible to explore this.

In our models, we considered the two outcomes separately, but they may be correlated. In other words, patients that suffer wound infection may be more likely to die. We intend to explore models that estimate these two outcomes jointly using seemingly unrelated regression techniques.

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