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HOW WELL DO DIAGNOSIS-RELATED GROUPS FOR APPENDECTOMY EXPLAIN VARIATIONS IN RESOURCE USE? AN ANALYSIS OF PATIENT-LEVEL DATA FROM 10 EUROPEAN COUNTRIES[†]

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ABSTRACT

Appendectomy is a common and relatively simple procedure to remove an inflamed appendix, but the rate of appendectomy varies widely across Europe. This paper investigates factors that explain differences in resource use for appendectomy.

We analysed 106 929 appendectomy patients treated in 939 hospitals in 10 European countries. In stage 1, we tested the performance of three models in explaining variation in the (log of) cost of the inpatient stay (seven countries) or length of stay (three countries). The first model used only the diagnosis-related groups (DRGs) to which patients were coded, the second model used a core set of general patient-level and appendectomy-specific variables, and the third model combined both sets of variables. In stage two, we investigated hospital-level variation.

In classifying appendectomy patients, most DRG systems take account of complex diagnoses and comorbidities but use different numbers of DRGs (range: 2 to 8). The capacity of DRGs and patient-level variables to explain patient-level cost variation ranges from 34% in Spain to over 60% in England and France. All DRG systems can make better use of administrative data such as the patient's age, diagnoses and procedures, and all countries have outlying hospitals that could improve their management of resources for appendectomy. Copyright © 2012 John Wiley & Sons, Ltd.

KEY WORDS: diagnosis-related groups; cost analyses; length of stay; appendectomy

1. INTRODUCTION

Appendectomy is a common and relatively simple procedure to remove an inflamed appendix. Despite the availability of advanced diagnostic technologies and well-established guidelines for its treatment (Sauerland *et al.*, 2006; Solomkin *et al.*, 2010), the rate of appendectomy varies widely across Europe: in 2008, the rate per 100 000 population ranged from 76 (Poland) to 181 (Austria) (OECD Health Data, 2010).

When used for funding, diagnosis-related group (DRG) classification systems are an important factor determining fairness and equity of payments to hospitals. If the DRG grouping fails to distinguish major factors influencing patient costs, hospitals may avoid treating costly cases (Street *et al.*, 2010). Using appendectomy as a case study and exploring data from 10 countries, this paper had three key objectives: (i) to identify factors that explain variations in resource use across patients; (ii) to assess the explanatory power of each country's DRGs relative

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to other patient and treatment characteristics; and (iii) to assess relative hospital performance in managing resources and the characteristics of hospitals that explain this performance.

2. METHODS

2.1. Data

Cases of appendectomy were identified using diagnostic and procedure codes. Eligible patients had a principal diagnosis of appendicitis or other disease of the appendix (ICD10 codes K35-K38 or equivalent) and had undergone an operation on the appendix (ICD9CM code 47.0 or equivalent). We included day cases (surgery without overnight stay), but excluded outpatients and inpatients aged less than 1 year.

Each of the 10 countries taking part in the study drew on locally available data. A tabulated summary of each country's data sources and description of the cross-country differences in costing methodologies are reported elsewhere (Street *et al*., 2012). The analysis was based on 2008 data in all countries except France (2007) and Poland (2009).

2.2. Regression strategy

Each country estimated three models for explaining variation in resource use across appendectomy patients: in the first model (M_D), the independent variables are the DRGs to which patients were coded, the second model uses a core set of patient-level variables (M_P), and the third specification includes both DRGs and patient-level variables (M_F). The dependant variable was either log of cost of the hospital stay (seven countries) or length of stay (LoS; three countries) (Table II). Further details of the methodological approach are reported in this issue (Street *et al*., 2012). In addition to the set of core patient and treatment variables, two appendectomy-specific variables were introduced into the equations: the first variable tests the impact of a common comorbidity (hypertension), and the second variable tests the use of laparoscopy (done or tried but failed), which is a less invasive procedure than open surgery (Sauerland *et al*., 2010). Cost analyses were run using OLS fixed effects (FESE) models. Exploratory analyses found no significant problems with over dispersion, so LoS analyses were run using Poisson models. Statistical significance was assessed at the 0.1% level.

3. RESULTS

3.1. DRG structure

Countries use different numbers of DRGs to classify appendectomy patients (Table I). Poland and Sweden use only two groups each, Spain uses six groups, and Germany uses eight.

Appendectomy DRGs are typically defined by diagnosis rather than by procedure, with eight countries differentiating cases with comorbidity or complications and four countries having a DRG for cases of complicated appendicitis (e.g. perforated or gangrenous). However, only the Spanish include a laparoscopy DRG. Half the countries modify DRGs by age, and France also adjusts by LoS and by whether the patient died. Further details of the DRG systems for appendectomy are reported elsewhere (Quentin *et al*., 2012).

In Table II, each country's DRGs are reported in ascending order of their associated reimbursement rate. The distribution of appendectomy patients across each country's set of DRGs is very variable. In Finland and Ireland, over 90% patients fall into a single DRG, whereas the most populated DRG in England, Germany and Spain has less than 60% of patients.

3.2. Descriptive statistics

The analysis included 106 929 patients treated in 939 hospitals in 10 European countries. As shown in Table II, the number of appendectomy cases assessed by each country ranges from 1480 (Finland) to 33 394 (England), and the

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Table I. Appendectomy DRGs: comparison across countries

	DRG-split variables					
Country (system)	Number of DRGs	Age	Length of stay	Primary diagnosis (complicated)	Complications/ co-morbidities	Death
Austria (LKF)	3	x	—	—	—	—
England (HRG)	3	x	—	—	x	—
Estonia (NordDRG)	4	—	—	x	x	—
Finland (NordDRG)	3	—	—	x	x	—
France (GHM)	5	x	x	x	x	x
Germany (G-DRG)	8	x	—	x	x	—
Ireland (AR-DRG)	3	x	—	—	x	—
Poland (JGP)	2	—	—	x	—	—
Spain (AP-DRG)	6	—	—	x	x	—
Sweden (NordDRG)	2	—	—	x	x	—

Key: x, split used; —, split not used; age splits are used to differentiate children/adults (Austria, England), older people (Austria, France, Ireland) and children (Germany). France uses LoS splits of 3, 4 and 5 days.

number of hospitals ranges from 5 (Finland) to 475 (Poland). Mean LoS varies from 1.9 days in Finland to 5.1 days in Germany. It is difficult to compare costs across countries because of variations in accounting rules and cost of living, partly exemplified by the observation that countries with similar LoS can have quite different costs.

Mean patient age ranges from 24 (Ireland) to 35 (Finland), and the percentage of male patients ranges from 46% (Germany) to 60% (Spain). In most countries, over 90% of patients are admitted as emergencies, but the figure is lower in France (40%) and Germany (59%). This may reflect differences in clinical practice, such as countries undertaking a significantly higher proportion of planned appendectomies than elsewhere, or it could reflect different coding practices.

The mean total number of diagnoses ranges from 1.0 in Finland to 2.6 in Germany, partly a reflection of variation in the depth of coding practice. In all countries, over 90% of patients have no recorded Charlson comorbidity.

The mean total number of procedures ranges from 1.0 (Estonia) to 4.4 (Finland). Just 1% of Estonian patients undergo a laparoscopic appendectomy, whereas in Germany the corresponding figure is 64%.

Germany has the highest recorded rates of urinary tract infection (UTI) (almost 3%), and Spain has the highest rate of wound infections (just over 3%). The mean rate of other surgical adverse events (such as sepsis, or accidental cut or puncture) was highest in England (0.6%).

3.3. Regression results

3.3.1. Stage 1. In the model with DRGs only (M_D), the coefficients for each of the DRG dummy variables are generally positive (in the cost equations) or greater than one (in the LoS equations) and significant at the 0.1% level, indicating that patients allocated to these DRGs have higher costs or longer stays than those in the highest volume DRG, which is the reference group (Table III). In all countries, except Finland and Germany, appendectomy without complication (lowest-cost category) is the reference group. Finland is an exception: appendectomy with complication represents 90% of the cases, reflecting their practice of allocating all patients admitted as emergencies to the most costly DRG (‘complicated principal diagnosis’ (DRG3)).

The DRGs are ordered in ascending order of their reimbursement rate, and the size of the coefficients should generally follow this ordering as prices are typically based on costs. There are exceptions, such as the negative coefficient for the DRG2 (appendectomy for those under 18 years of age) in the cost equations for England, and a coefficient <1 in Austria’s LoS analysis for DRG2 (under 15 years of age). In England, this suggests that these patients are, on average, less costly to care for than those in the reference DRG despite their reimbursement being higher. In Austria, the costs of these patients are unobserved and may not be strongly correlated with LoS.

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Table II. Appendectomy data: descriptive statistics by country

Country	Austria	Ireland	Poland	England	Estonia	Finland	France	Germany	Spain	Sweden
Dependent variable	LoS	LoS	LoS	Log cost	Log cost	Log cost	Log cost	Log cost	Log cost	Log cost
No. patients	13 202	5813	31 105	33 394	2113	1480	9948	2451	1814	5609
% national cases (approx)*	88%	88%	100%	85%	96%	24%	11%	2%	4%	52%
No. hospitals	112	37	475	151	18	5	82	22	8	29
Variables, patient[a]					*Percentage of patients (%)*					
append_DRG1	64.9	92.8	71.6	58.1	83.2	7.0	66.7	4.0	59.1	76.9
append_DRG2	30.3	1.7	28.4	34.7	3.3	1.4	26.7	51.7	24.9	22.5
append_DRG3	2.6	4.8		4.0	10.5	91.5	2.1	9.5	6.8	
append_DRG4					3.0		1.7	4.8	4.4	
append_DRG5							1.2	16.5	2.6	
append_DRG6								3.3	1.5	
append_DRG7								2.2		
append_DRG8								4.8		
append_DRGot	2.3	0.8	0.0	3.2	0.0	0.2	1.7	3.3	0.7	0.7
gender	47.9	55.7	51.5	55.6	50.1	52.0	0.5	45.8	59.5	56.4
trans_in	0.4	0.9	NA	4.1	12.2	0.6	1.8	0.5	0.1	7.5
trans_out	0.2	0.5	0.3	0.4	19.1	0.7	0.5	0.3	0.1	2.2
emergency	90.8	98.1	93.2	97.7	97.0	90.8	40.0	59.3	98.5	94.6
deceased	0.0	NA	0.1	0.1	0.0	0.1	0.0	0.0	0.1	0.0
ch_index 0	98.2	98.1	99.2	99.2	94.5	99.5	96.2	93.9	93.4	95.6
ch_index 1	1.4	1.6	0.6	0.6	1.2	0.2	3.1	4.0	5.4	4.0
ch_index 2	0.4	0.3	0.2	0.2	1.1	0.3	0.7	2.1	1.2	0.4
adv_event	0.1	0.3	0.1	0.6	0.1	0.3	0.3	0.5	0.3	0.4
urinary tract infection	0.5	0.4	0.1	0.5	0.1	0.1	0.4	2.6	0.2	0.1
wound infection	0.3	1.3	0.1	1.3	0.5	0.1	0.6	1.8	3.2	0.4
hypertension	1.7	0.7	0.6	3.5	1.6	0.0	2.7	8.4	5.8	3.8
laparoscopy	16.2	51.6	9.5	27.1	1.1	25.5	59.4	63.9	34.3	27.8
					Mean (SD)					
cost	NA	NA	NA	£2486 (£1009)	€662 (€447)	€2930 (€1003)	€2421 (€1236)	€2464 (€1026)	€3401 (€1692)	SEK36 384 (SEK17 289)
log cost	NA	NA	NA	7.7 (0.4)	6.4 (0.3)	7.9 (0.3)	7.7 (0.4)	7.7 (0.4)	8.0 (0.5)	10.4 (0.5)
los	4.5 (2.1)	3.7 (2.2)	5.0 (2.6)	3.5 (3.0)	3.2 (2.5)	1.9 (1.6)	4.1 (2.4)	5.1 (2.6)	3.9 (2.9)	2.5 (1.8)
age	25 (16.8)	24 (14.4)	28 (17.9)	29 (17.2)	29 (18.0)	35 (17.2)	25 (17.7)	30 (19.6)	33 (18.8)	31 (18.4)
totdiag	1.3 (0.8)	1.5 (1.1)	1.2 (0.4)	1.7 (1.3)	1.2 (0.6)	1.04 (0.3)	1.6 (1.0)	2.6 (2.0)	1.9 (1.5)	1.3 (0.7)
totproc	1.2 (0.6)	2.2 (0.7)	3.4 (2.5)	1.5 (1.0)	1.0 (0.0)	4.41 (1.2)	2.5 (1.8)	1.5 (1.1)	1.4 (0.8)	1.4 (0.7)
Variables, hospital					*Percentage of hospitals (%)*					
teach	2.7	21.6	7.6	14.6	5.6	20.0	12.2	NA	50.0	27.6
private	10.7	NA	NA	0.0	0.0	0.0	61.0	0.0	NA	0.0
urban	67.9	NA	98.1	NA	33.3	NA	54.9	NA	37.5	37.9
					Mean (SD)					
totvol1000	21.27 (19.91)	32.49 (25.74)	13.61 (10.40)	84.08 (45.25)	13.27 (13.21)	90.52 (142.39)	29.98 (28.72)	20.18 (13.33)	32.09 (24.69)	28.43 (26.37)
append_percent	0.62 (0.35)	0.66 (0.36)	0.56 (0.13)	0.30 (0.12)	1.19 (0.51)	0.32 (0.10)	0.59 (0.52)	0.73 (0.50)	0.83 (0.22)	0.73 (0.29)
spec_index	0.36 (0.14)	0.42 (0.12)	NA (NA)	0.18 (0.11)	NA	0.20 (0.04)	0.46 (0.18)	0.34 (0.13)	NA	0.17 (0.10)
adv_event_1	2.20 (2.00)	13.45 (9.80)	13.00 (9.00)	15.15 (5.60)	0.50 (0.10)	17.76 (6.25)	12.98 (8.43)	44.60 (17.15)	0.30 (0.27)	24.91 (8.78)
adv_event_2	2.79 (1.97)	6.04 (3.05)	1.00 (1.00)	7.04 (2.29)	0.00 (0.01)	18.48 (2.30)	7.88 (5.06)	16.77 (7.25)	0.10 (0.04)	12.40 (2.61)

Notes: NA, not available; in Ireland, mortality data are not reported to protect patient confidentiality. *Based on OECD 2008 data and Hospital Episode Statistics (England only). [a]DRG variables ordered by ascending DRG weights (DRGs vary by country).

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Table III. Appendectomy regression analyses: results (Part 1)

	DEPENDENT VARIABLE: LOG OF COST														
	England			Estonia			Finland			France			Germany		
Explanatory variable	M_D	M_P	M_F	M_D	M_P	M_F	M_D	M_P	M_F	M_D	M_P	M_F	M_D	M_P	M_F
DRG1	*ref*		*ref*	*ref*		*ref*	-0.125***		-0.128***	*ref*		*ref*	0.099**		-0.103***
DRG2	-0.058***		-0.077***	0.411***		0.297***	-0.370***		-0.420***	0.320***		0.274***	*ref*		*ref*
DRG3	0.351***		0.262***	0.457***		0.452***	*ref*		*ref*	0.314***		0.150***	0.056**		-0.072**
DRG4				0.946***		0.809***				0.666***		0.475***	0.056		-0.105*
DRG5										0.840***		0.517***	0.316***		0.196***
DRG6													0.313***		0.151***
DRG7													0.296***		0.100
DRG8													0.625***		0.265***
Other DRGs	0.356***		0.276***	0.410***		0.271***	0.563***		0.571***	0.636***		0.388***	0.434***		0.035
Age: 1-10 years		0.017**	0.018**		0.020	-0.017		-0.047	-0.041		0.009	0.004		0.008	0.053
Age: 11-15 years		*ref*	*ref*		*ref*	*ref*		*ref*	*ref*		*ref*	*ref*		*ref*	*ref*
Age: 16-20 years		0.016**	-0.014**		-0.011	0.003		-0.139***	-0.139***		-0.063***	-0.066***		-0.144***	-0.186***
Age: 21-35 years		0.055***	-0.029***		0.025	0.015		-0.136***	-0.134***		-0.083***	-0.082***		-0.136***	-0.179***
Age: 36+ years		0.077***	-0.013		0.080***	0.025		-0.061*	-0.057		0.054***	0.001		-0.049*	-0.114***
Male		-0.002	-0.004		0.021	-0.002		-0.021	-0.017		0.001	-0.017**		0.015	-0.006
No. of diagnoses		0.028***	0.013***		0.186***	0.070***		0.168***	0.169***		0.073***	0.042***		0.052***	0.036***
No. of procedures		0.046***	0.027***		0.000	0.000		0.047***	0.042***		0.089***	0.077***		0.112***	0.109***
Transfer in		0.082***	0.081***		-0.015	-0.009		0.265**	0.251**		0.120***	0.071*		0.037	0.028
Transfer out		0.051	0.035		-0.018	0.001		0.129	0.119		0.066	0.047		-0.076	-0.117
Emergency		0.353***	0.361***		-0.022	0.025		0.199***	0.167***		0.001	-0.009		0.000	-0.005
Deceased		-0.001	-0.005		0.000	0.000		0.472***	0.461***		0.169	0.129		0.000	0.000
Charlson index = 1		-0.025***	-0.013*		-0.135	-0.143*		-0.182*	-0.194*		-0.056**	-0.032*		-0.067	-0.045
Charlson index = 2		0.022	-0.012		0.025	-0.038		-0.287*	-0.309*		-0.041	-0.065		-0.061	-0.063
Hypertension		-0.011	0.002		0.000	0.000		0.000	0.000		0.029	0.024		-0.006	0.009
Laparoscopy		-0.055***	-0.038***		0.136***	0.132***		0.281***	0.298***		0.053***	0.064***		0.028	0.039*
Adverse event		0.146***	0.075*		0.546	0.757*		0.491***	0.480***		0.131*	-0.023		0.026	0.018
Urinary tract infection		-0.025	0.020		-0.340	-0.218		-0.791***	-0.651***		-0.108**	-0.115**		0.026	-0.013
Wound infection		0.258***	0.125***		0.510***	0.227		-0.600*	-0.591		0.407***	0.154**		0.262***	0.158**
Intercept	7.735***	7.244***	7.351***	6.335***	6.148***	6.239***	7.938***	7.392***	7.444***	7.563***	7.327***	7.328***	7.614***	7.483***	7.532***
Adjusted R²	0.617	0.609	0.644	0.487	0.2246	0.527	0.317	0.474	0.507	0.581	0.585	0.665	0.372	0.469	0.527

*p<0.05, **p<0.01, ***p<0.001. Key: M_D: DRG model; M_P: patient characteristics model; M_F: full model.

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Table III. Appendectomy regression analyses: results (Part 2)

	DEPENDENT VARIABLE: LOG OF COST						DEPENDENT VARIABLE: LENGTH OF STAY								
	Spain			Sweden			Austria			Ireland			Poland		
	M_D	M_P	M_F	M_D	M_P	M_F	M_D	M_P	M_F	M_D	M_P	M_F	M_D	M_P	M_F
DRG1	*ref*		*ref*	*ref*		*ref*	*ref*		*ref*	*ref*		*ref*	*ref*		*ref*
DRG2	0.141***		-0.134*	0.335***		0.296***	0.981*		0.998	1.035		0.832***	1.395***		1.284***
DRG3	0.428***		0.361***				1.785***		1.281***	2.131***		1.417***			
DRG4	0.416***		0.236***												
DRG5	0.737***		0.414***												
DRG6	0.619***		0.279***												
Other DRGs	0.547***		0.179	0.595***		0.417***	1.651***		1.096**	2.178***		1.098			
Age: 1-10 years		0.128**	0.128**		0.033	0.006		0.984	0.985		1.065**	1.057**		1.039***	1.033***
Age: 11-15 years		*ref*	*ref*		*ref*	*ref*		*ref*	*ref*		*ref*	*ref*		*ref*	*ref*
Age: 16-20 years		-0.159***	-0.132***		-0.073***	-0.062***		0.954***	0.950***		0.960	0.956*		0.903***	0.909***
Age: 21-35 years		-0.125***	-0.105**		-0.083***	-0.063***		0.951***	0.946***		1.017	1.015		0.881***	0.881***
Age: 36+ years		0.021	0.018		0.009	-0.004		1.182***	1.146***		1.237***	1.220***		1.136***	1.104***
Male		0.052**	0.045*		-0.030**	-0.038***		1.002	1.006		0.952***	0.946***		1.038***	1.021***
No. of diagnoses		0.050***	0.025**		0.080***	0.037***		1.085***	1.077***		1.085***	1.052***		1.161***	1.080***
No. of procedures		0.090***	0.070***		0.117***	0.097***		1.212***	1.200***		1.158***	1.167***		1.057***	1.052***
Transfer in		-0.558***	-0.568***		0.008	-0.015		1.097	1.111		1.157	1.177			
Transfer out		-0.041	-0.103		-0.045	-0.082		0.781	0.770		0.739	0.711*		0.984	0.987
Emergency		0.117	0.112		0.090*	0.106**		1.074***	1.076***		1.433***	1.420***		0.994	0.981
Deceased		0.707***	0.645***		0.279***	0.165***		0.696	0.630		0.301***	0.311***		0.849	0.845
Charlson index = 1		-0.013	0.020		-0.003	-0.019		1.04	1.021		0.966	0.956		1.017	1.087*
Charlson index = 2		0.028	-0.001		0.076	0.093		0.954	0.903		0.972	0.833		0.942	0.971
Hypertension		-0.03	0.004		-0.039	0.005		1.003	0.967		0.866	0.971		0.907*	0.992
Laparoscopy		0.135***	0.280***		0.057***	0.083***		0.982	0.988		0.928***	0.932***		0.854***	0.862***
Adverse event		0.092	0.041		0.343***	0.209*		1.208	1.145		1.037	0.928		1.339**	1.250*
Urinary tract infection		-0.168	-0.290***		-0.022	-0.169***		1.107	1.096		1.212*	0.947		0.981	1.059
Wound infection		0.450***	0.241***		0.369***	0.284***		1.510***	1.545***		1.422***	1.197**		1.644***	1.674***
Intercept	7.867***	7.585***	7.599***	10.315***	10.072***	10.069***	4.281***	2.872***	2.924***	3.431***	1.612***	1.665***	4.312***	3.351***	3.525***
Adjusted R^2	0.272	0.292	0.344	0.450	0.424	0.485									
Adjusted deviance R^2							0.178	0.342	0.352	0.212	0.332	0.350	0.316	0.354	0.398

*$p<0.05$, **$p<0.01$, ***$p<0.001$. Key: M_D: DRG model; M_P: patient characteristics model; M_F: full model.

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The second model (M_P) estimates the influence of a number of patient and episode characteristics on the cost or LoS of appendectomy patients (Street *et al.*, 2012). Although not always significant, there appears to be a U-shaped relationship between age and LoS, with younger (<11) and older (>35) age groups tending to have longer stays. The relationship between cost and age is less clear, although patients aged between 16 and 35 years tend to have lower costs.

Despite the differences in coding practices across countries, Table III shows that the total number of recorded diagnoses and procedures per patient is always significant in explaining resource use. Where significant, those who are admitted as emergencies tend to have a longer stay or higher costs. Being transferred into hospital significantly increases cost in England and France, but being transferred out has no impact on resource use in any country.

Patients who die in hospital have shorter stays but higher costs, although this relationship is not always statistically significant (there are very few deaths). After controlling for the total number of coded diagnoses, comorbidities (as assessed by the Charlson index and hypertension) are seldom significant predictors of LoS and cost. Surprisingly, English and French patients with one, non-severe, Charlson comorbidity tend to be less costly than those with no comorbidities. This apparently counterintuitive finding arises because of the partial correlation (in the order of $r = 0.4$) between this variable and that measuring total diagnoses.

Laparoscopy is associated with shorter LoS in Ireland and Poland. In most countries, cost is significantly higher in patients undergoing laparoscopy, the exceptions being England (significantly lower costs) and Germany (non-significant effect).

Patients who suffer post-operative wound infection are likely to have hospital stays of between 42% and 64% longer than those who do not; where statistically significant, costs tend to be between 29% and 67% higher too, calculated as $\exp(\hat{\beta}) - 1$ (Halvorsen and Palmquist, 1980). Other adverse events tend to increase cost but have no significant impact on LoS. UTIs are associated with lower cost in some countries, but do not influence LoS.

Some of the variables used in patient variable model (M_P)—such as age, complications and comorbidities—are often used in the construction of DRG systems. In the full model (M_F), DRGs are introduced in addition to the patient variables used in M_P to compare their contribution to overall explanatory power of the first two models. In a given country, if DRGs are successfully capturing variations in resource use due to patient-level variables, the explanatory power of M_F and M_D should be similar. Also, if the DRGs are even partially capturing the impact of these patient variables, the coefficients for the latter will be smaller in M_F than in M_P (Street *et al.*, 2012). This pattern is evident in most countries for total diagnoses, total procedures and age (although the impact of age is mainly evident in the cost equations). In the DRG model (M_D), the *R*-squared statistic provides a proxy measure of the capacity of a DRG system to explain variations in resource use for individual patients, whereas in our full specification (M_F), the *R*-squared is driven both by DRGs and patient variables.

Comparing the *R*-squared values from M_F with those from M_P and M_D, we see that the capacity of DRGs and patient-level variables to explain cost variation among patients varies widely across countries (Table III, Parts 1 and 2). M_P explains around 60% of the variation in the cost of patients in England and France, but less than 30% of cost variation amongst Spanish patients. In England and Sweden, the DRGs are better than the patient-level variables at explaining variation, suggesting that country-specific refinements made to the DRG system are effective. However, because the Swedish DRG model has lower explanatory power than the full model, Sweden could further improve its DRG system by incorporating additional patient-level information.

In Finland, Germany and Spain, M_P performs substantially better than M_D at explaining variation in cost. This suggests that there is significant potential to improve the DRG system in these countries by taking greater account of the variables used in M_P. For example, the Spanish DRG system takes no account of patient age, but the regression results show that young adults are significantly less costly than the reference group (patients aged 11 to 15 years).

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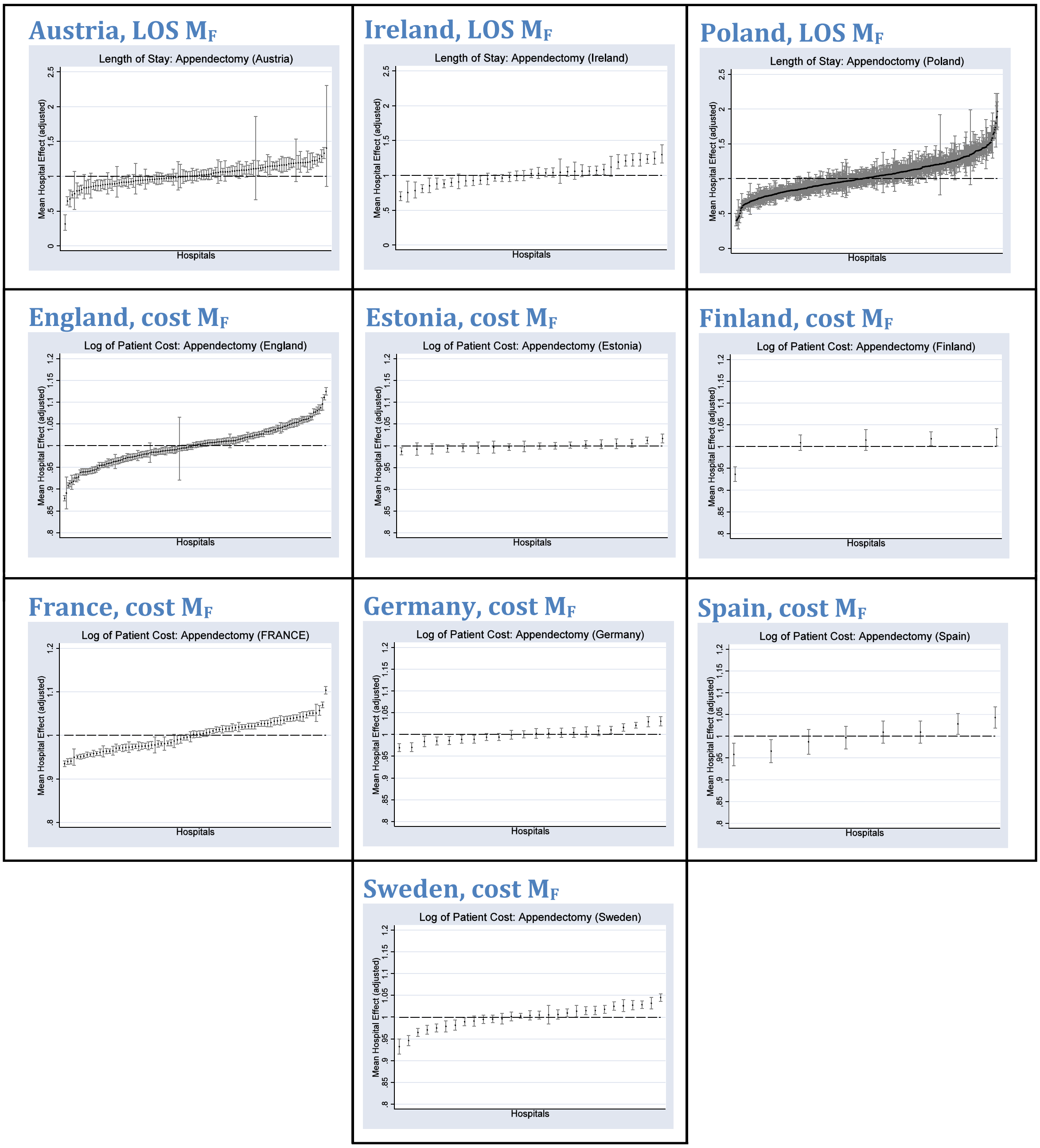

Figure 1. Unexplained variation in resource use across hospitals

In France, the explanatory power of the two partially specified models (M_D and M_P) is similar and a little below the explanatory power of the fully specified model. The two sets of variables are therefore performing the same role and can be considered virtually interchangeable.

In the LoS analyses, patient-level variables generally perform better than the DRGs in Austria, Ireland and (to a lesser degree in) Poland. Although all three DRG systems could benefit by incorporating additional patient and treatment information, the Austrian system appears to have the greatest capacity to improve.

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3.3.2. Stage 2. Figure 1 presents the unexplained variance in costs or LoS across hospitals, once the differences in patient-level variables and DRGs are controlled for. In each country, hospitals are ranked by their deviation from the average (national) cost of appendectomy. Hospitals on the left-hand side have lower costs than average, whereas those on the right-hand side have higher costs. We see that, even after controlling for measurable characteristics of patients and the DRGs to which they are allocated, there are large variations in the average cost or LoS of appendectomy cases across hospitals within each country.

All countries include hospitals with costs/LoS that are significantly above (or significantly below) the national average. In England, France, Sweden and, to a lesser extent, Poland, hospitals at the extremes are notably different from the majority of hospitals in the same country.

Austria, France, Ireland, Poland, England, Germany and Spain undertook second-stage analyses of average costs/LoS across hospitals, using estimated hospital fixed effects from stage 1 as the dependent variable (Street *et al*., 2012). Results are available on the EuroDRG website (http://www.eurodrg.eu). There is some evidence of economies of scale in Austrian hospitals: higher activity volume is associated with shorter stays. In France, the greater the number of appendectomy cases as a percentage of the hospital's overall workload, the lower their average cost. In England, more specialised hospitals have significantly higher costs. None of the other explanatory variables that we tested was found to be significant.

4. DISCUSSION

We have analysed routinely available data in 10 countries to address three objectives: first, to examine factors that explain variations in costs or LoS of patients who have had an appendectomy, by exploring the patients' demographic, diagnostic and treatment-related characteristics; second, to assess the explanatory power of DRG systems in explaining variations in resource use relative to other patient and treatment characteristics; and third, to assess the size and determinants of variations in hospital performance within selected countries. The data for each country's patients are analysed independently, but common patterns are evident.

In all countries, patient age and the number of recorded diagnoses were significant explanatory variables of both cost and LoS. In contrast, the comorbidities used to construct the Charlson index had limited explanatory power. The index was originally developed to predict hospital mortality but is being used increasingly to assess variation in costs and LoS (Cher and Lenert, 1997; Luzier *et al*., 2002; Guo *et al*., 2008; Polverejan *et al*., 2003). Our analysis suggests that a simple count of diagnoses may be better than the Charlson index at explaining resource use for appendectomy patients.

Our findings on the impact of laparoscopy on resource use were mixed. Although associated with shorter stays in Ireland and Poland, and lower cost in England, laparoscopy is more frequently linked with significantly *higher* costs, a finding supported by other studies (Williams *et al*., 1996; Yau *et al*., 2007; Schreyögg, 2008). But, these higher costs may be justifiable, as laparoscopy is associated with lower rates of wound infection (Guller *et al*., 2004; Sauerland *et al*., 2010).

The countries in our study use diverse approaches to constructing DRGs for patients who have an appendectomy despite it being a standardised procedure. Although almost all countries distinguish complicated and uncomplicated appendectomies, the number of DRG categories and the basis by which patients are categorised to one DRG or another vary widely.

Our results suggest that more is not necessarily better when constructing DRGs: Sweden, which uses two DRGs, appears to explain variation in costs better than Germany, which uses eight DRGs. Moreover, although we have identified significant explanators of resource use, this is only the first step in assessing how they might be used to refine the DRG system. For example, although age appears to be important in explaining cost, DRG systems that incorporate extensive age adjustments—such as in Germany—do not necessarily explain cost variation better. Further research to assess the role of age (and other significant characteristics) in determining resource homogenous groupings would be the next step.

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Despite appendectomy being a reasonably standardised procedure, there is considerable variation in the average cost or LoS of patients undergoing this procedure across hospitals, both within and across countries. Controlling for the characteristics of the appendectomy patients in each hospital and for the quality of care, our results identified a small number of country-specific factors that may drive hospital performance. But the wide unexplained variation may be driven by unobserved factors, including how access to the operating theatre is managed, how discharge policies are implemented or how well staff work as a team. Our analysis indicates which hospitals may merit further investigation to obtain intelligence on these matters and provide examples of good or bad organisational practice.

Our study suffers the usual limitations associated with use of routine administrative data, notably its reliance on constructing explanatory variables from the source data and measurement bias relating to how data are recorded. A common set of variables was used to enable a standard model specification to be applied by all countries, but we cannot exclude the possibility that we omitted some important explanatory patient variables. The study is also afflicted by cross-country differences in coding depth and differences in how particular variables are defined. This is particularly relevant for coding of the secondary diagnoses, which are also used for identifying adverse hospital events. Differences in hospital cost-accounting methods and the way costs are constructed may also explain observed variation in costs both across and within countries (Tan *et al*., 2011). These concerns rule out analysis of pooled data across countries and underpin our decision to estimate country-specific models. As such, the observed cross-country patterns should be interpreted cautiously.

Despite these limitations, the analysis provides valuable insights into which factors drive variations in costs and LoS for appendectomy patients, and the ability of the different DRG systems to capture this variation. In all 10 countries examined, we find wide variations in unexplained average hospital costs or length of stay. Our findings suggest that there is scope for improving the DRGs in many countries, and all countries have hospitals that could improve their productivity or their management of resources for these appendectomy patients. These matters merit further investigation.

CONFLICT OF INTEREST

The authors have declared that there is no conflict of interest.

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