

Supplementary Appendix

This appendix has been provided by the authors to give readers additional information about their work.

Supplement to: Jencks SF, Williams MV, Coleman EA. Rehospitalizations among patients in the Medicare fee-for-service program. *N Engl J Med* 2009;360:1418-28.

APPENDIX

Our objective was to identify DRGs for which an important fraction of 30-day rehospitalizations were “planned” (that is, occurred by choice rather than because of clinical deterioration). The plan may reflect an elective hospitalization unrelated to the index hospitalization, a hospitalization to complete care that could not be completed efficiently within a single hospitalization, or a hospitalization deliberately separated from the original hospitalization to maximize revenue (gaming).

In general, unplanned rehospitalization is most frequent in the first day or two after the last discharge and becomes less frequent with the passage of time. We hypothesized that rehospitalizations resulting from clinical deterioration (e.g.: heart failure, pneumonia, sepsis, etc), would decrease exponentially with time after discharge in a DRG-specific way:

$$(1) \quad \text{rehospitalization rate}_{t, \text{DRG}} = \text{baseline}_{\text{DRG}} + b_{\text{DRG}} \cdot e^{-k_{\text{DRG}} t}.$$

For computational purposes, we restate equation (1) as

$$(2) \quad \log(\text{rehospitalization rate}_{t, \text{DRG}} - \text{baseline}_{\text{DRG}}) = b_{\text{DRG}} + k_{\text{DRG}} t.$$

Rehospitalizations_{t, DRG} is the number of hospitalizations assigned to that DRG that occurred exactly t days after a short-stay hospital discharge for any reason.

Baseline_{DRG} is the average daily number of rehospitalizations for this DRG between 160 and 200 days after the index hospitalization.

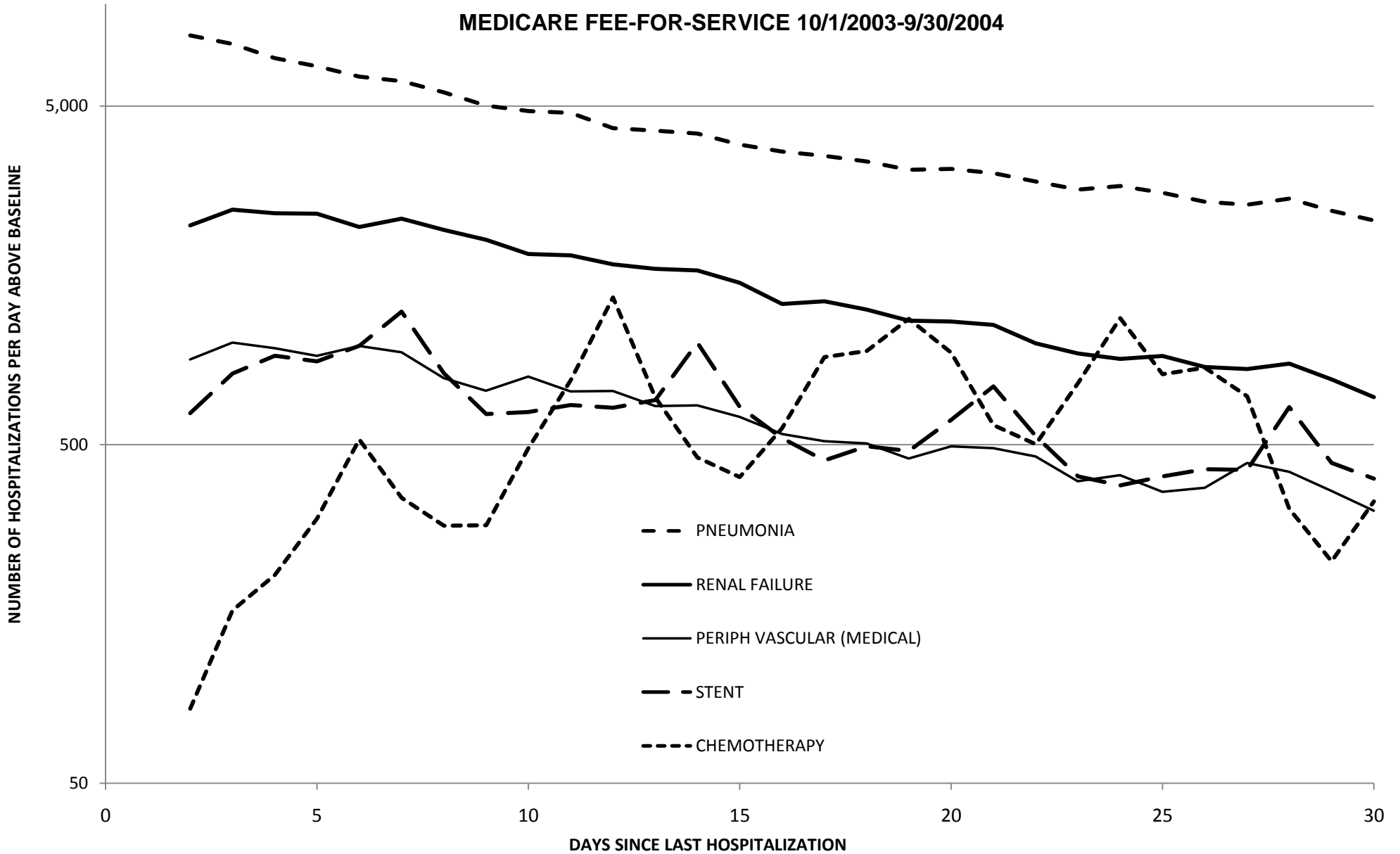
For each of the 100 most frequent rehospitalization DRGs (73.2% of all rehospitalizations) we then estimated b_{DRG} and k_{DRG} , using ordinary least squares regression, and computed R^2 for the fit of the observational data to the resulting model.

Figure App-1 plots the log of the daily number of rehospitalizations for pneumonia ($R^2=0.98$ $k=-0.039$ to -0.044), renal failure ($R^2=0.90$, $k=-0.035$ to -0.046), peripheral vascular disease with

medical care ($R^2=0.87$, $k= -.029$ to $-.040$), drug-eluting stent ($R^2=0.67$, $k= -0.017$ to -0.034), and chemotherapy ($R^2=0.18$, $k= -0.062$ to -0.005) against the number of days since the last discharge. Because the number of rehospitalizations is on a logarithmic scale, the relatively straight lines for pneumonia, renal failure, and medical care of peripheral vascular disease represent the exponential decrease in rehospitalizations that we hypothesized and the high R^2 s indicate that the fit is quite good. The fact that the lines are roughly parallel means that rate of decrease in the risk of rehospitalization (k) for each of these conditions is similar. By contrast, the frequency of rehospitalizations for placement of a drug-eluting stent has spikes 1, 2, 3, and 4 weeks after discharge, strongly suggesting an element of planning (and leading to a lower R^2), and also has a slower rate of decline (perhaps because planned rehospitalizations are mixed with unplanned rehospitalizations). Finally, rehospitalization for chemotherapy actually becomes more frequent with longer time from discharge and the R^2 is quite low, so planning is still more likely.

Table App-1 shows the 100 most frequent DRGs, the regression coefficient (k) for time since last discharge (see equations above), R^2 , and the cumulative percent of the top 100 rehospitalization DRGs. This information provides a semi-quantitative framework for estimating the percentage of rehospitalizations that are planned. Almost all of the DRGs with an R^2 greater than 0.85 or with an estimated k whose lower confidence limit is greater than -0.35 appear to represent rehospitalizations that would rarely be planned. We have shaded the cells where the title of the DRG, the value of R^2 , or the value of k suggest that planned rehospitalizations are frequent. From this information we designated 19 DRGs (marked with a ✓), representing 9.4% of discharges in the top 100 DRGs, as “often planned”. We assumed that the same percentage applies to the remaining 380 DRGs, but lower volume of rehospitalizations prevents applying the same statistical methods.

FIGURE APP-1
FREQUENCY OF HOSPITALIZATION FOR FIVE CONDITIONS
ACCORDING TO DAYS SINCE LAST HOSPITALIZATION FOR ANY REASON
MEDICARE FEE-FOR-SERVICE 10/1/2003-9/30/2004



APPENDIX TABLE 1

REHOSPITALIZATIONS WITHIN 30 DAYS OF HOSPITAL DISCHARGE

DRG FOR REHOSPITALIZATION	MS	Total Re-hospitalizations	Rate of change over time (k) (95% CI)	RSQ	Cum Pct of Rehs
127 Heart Failure & Shock	M	176,125	-0.032 to -0.034	0.990	9.4%
174 G.I. Hemorrhage w CC	M	52,353	-0.044 to -0.049	0.985	12.2%
078 Pulmonary Embolism	M	12,148	-0.050 to -0.057	0.978	12.9%
182 Esophagitis, Gastroent & Misc Digest Disorders Age >17 w CC	M	68,367	-0.040 to -0.045	0.978	16.5%
076 Other Resp System O.R. Procedures w CC	S	10,623	-0.042 to -0.047	0.977	17.1%
204 Disorders Of Pancreas Except Malignancy	M	14,333	-0.043 to -0.049	0.975	17.8%
143 Chest Pain	M	31,539	-0.039 to -0.044	0.975	19.5%
079, 080, 081, 089, 090, 091 Pneumonia & Pulmonary Infections	M	147,185	-0.039 to -0.044	0.975	27.4%
087 Pulmonary Edema & Respiratory Failure	M	21,244	-0.038 to -0.043	0.974	28.5%
249 Aftercare, Musculoskeletal System & Connective Tissue	M	7,771	-0.046 to -0.052	0.973	29.0%
144 Other Circulatory System Dx w CC	M	34,352	-0.050 to -0.057	0.971	30.8%
132 Atherosclerosis w CC	M	20,457	-0.040 to -0.046	0.970	31.9%
475 Respiratory System Dx With Ventilator Support	S	29,409	-0.047 to -0.054	0.969	33.5%
452 Complications Of Treatment w CC	M	11,463	-0.079 to -0.091	0.969	34.1%
331 Other Kidney & Urinary Tract Dx Age >17 w CC	M	15,307	-0.044 to -0.051	0.967	34.9%
138 Cardiac Arrhythmia & Conduction Disorders w CC	M	36,608	-0.041 to -0.048	0.967	36.8%
099 Respiratory Signs & Symptoms w CC	M	4,639	-0.051 to -0.059	0.965	37.1%
416 Septicemia Age >17	M	63,416	-0.036 to -0.042	0.964	40.5%
468 Extensive O.R. Procedure Unrelated To Principal Dx	U	10,776	-0.040 to -0.046	0.963	41.1%
320 Kidney & Urinary Tract Infections Age >17 w CC	M	42,612	-0.025 to -0.030	0.962	43.3%
463 Signs & Symptoms w CC	M	9,265	-0.048 to -0.056	0.961	43.8%
124 Circulatory Disorders Except Ami, w Card Cath & Complex Dx	M	16,210	-0.037 to -0.044	0.957	44.7%
430 Psychoses	M	75,622	-0.044 to -0.052	0.957	48.7%
172 Digestive Malignancy w CC	M	7,579	-0.040 to -0.047	0.955	49.1%
419 Fever Of Unknown Origin Age >17 w CC	M	4,574	-0.051 to -0.061	0.954	49.4%
082 Respiratory Neoplasms	M	15,435	-0.037 to -0.044	0.953	50.2%
483 No Longer Valid	S	8,315	-0.050 to -0.059	0.953	50.7%
296 Nutritional & Misc Metabolic Disorders Age >17 w CC	M	65,967	-0.038 to -0.045	0.953	54.2%
018 Cranial & Peripheral Nerve Disorders w CC	M	8,571	-0.040 to -0.047	0.950	54.6%
170 Other Digestive System O.R. Procedures w CC	S	4,930	-0.046 to -0.056	0.949	54.9%
180 G.I. Obstruction w CC	M	19,639	-0.048 to -0.058	0.949	56.0%
442 Other O.R. Procedures For Injuries w CC	S	5,858	-0.060 to -0.072	0.948	56.3%
183 Esophagitis, Gastroent & Misc Digest Disorders Age >17 w/o CC	M	10,704	-0.043 to -0.052	0.948	56.8%
297 Nutritional & Misc Metabolic Disorders Age >17 w/o CC	M	7,134	-0.042 to -0.051	0.947	57.2%
449 Poisoning & Toxic Effects Of Drugs Age >17 w CC	M	8,463	-0.042 to -0.050	0.945	57.7%
123 Circulatory Disorders w AMI, Expired	M	6,792	-0.050 to -0.061	0.942	58.0%
088 Chronic Obstructive Pulmonary Disease	M	73,410	-0.022 to -0.027	0.942	62.0%
243 Medical Back Problems	M	13,013	-0.036 to -0.043	0.942	62.7%
139 Cardiac Arrhythmia & Conduction Disorders w/o CC	M	7,765	-0.041 to -0.050	0.940	63.1%

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	DRG FOR REHOSPITALIZATION	MS	Total Re-hospitalizations	Rate of change over time (k) (95% CI)	RSQ	Cum Pct of Rehs
	294 Diabetes Age >35	M	20,680	-0.046 to -0.056	0.939	64.2%
	188 Other Digestive System Dx Age >17 w CC	M	24,603	-0.060 to -0.073	0.938	65.5%
	207 Disorders Of The Biliary Tract w CC	M	6,222	-0.040 to -0.048	0.938	65.8%
	101 Other Respiratory System Dx w CC	M	5,572	-0.056 to -0.069	0.935	66.1%
	523 Alcohol/Drug Abuse Or Dependence w/o Rehab w/o CC	M	5,331	-0.046 to -0.056	0.934	66.4%
	521 Alcohol/Drug Abuse Or Dependence w CC	M	8,813	-0.042 to -0.052	0.933	66.9%
	015 Nonspecific CVA & Precerebral Occlusion w/o Infarct	M	9,709	-0.042 to -0.052	0.931	67.4%
	085 Pleural Effusion w CC	M	7,029	-0.041 to -0.051	0.930	67.8%
	205 Disorders Of Liver Except Malig,Cirr,Alc Hepa w CC	M	10,665	-0.042 to -0.052	0.928	68.3%
	429 Organic Disturbances & Mental Retardation	M	10,549	-0.045 to -0.056	0.925	68.9%
	125 Circulatory Disorders Except Ami, w Card Cath w/o Complex Dx	M	9,347	-0.043 to -0.053	0.925	69.4%
	121 Circulatory Disorders w Ami & Major Comp, Discharged Alive	M	25,039	-0.043 to -0.054	0.923	70.7%
	014 Intracranial Hemorrhage Or Cerebral Infarction	M	27,322	-0.048 to -0.061	0.921	72.2%
	493 Laparoscopic Cholecystectomy w/o C.D.E. w CC	S	7,282	-0.035 to -0.044	0.921	72.6%
	148 Major Small & Large Bowel Procedures w CC	S	18,514	-0.040 to -0.050	0.918	73.6%
	012 Degenerative Nervous System Disorders	M	13,382	-0.044 to -0.055	0.917	74.3%
	154 Stomach, Esophageal & Duodenal Procedures Age >17 w CC	S	4,695	-0.046 to -0.058	0.916	74.5%
	116 Other Permanent Cardiac Pacemaker Implant	S	13,555	-0.032 to -0.040	0.914	75.3%
	096 Bronchitis & Asthma Age >17 w CC	M	7,544	-0.025 to -0.032	0.914	75.7%
	203 Malignancy Of Hepatobiliary System Or Pancreas	M	6,939	-0.040 to -0.051	0.913	76.0%
	300 Endocrine Disorders w CC	M	5,034	-0.041 to -0.053	0.911	76.3%
	210 Hip & Femur Procedures Except Major Joint Age >17 w CC	S	10,737	-0.021 to -0.026	0.911	76.9%
	024 Seizure & Headache Age >17 w CC	M	13,028	-0.042 to -0.054	0.906	77.6%
	418 Postoperative & Post-Traumatic Infections	M	16,855	-0.055 to -0.070	0.906	78.5%
	034 Other Disorders Of Nervous System w CC	M	5,462	-0.046 to -0.059	0.905	78.8%
	239 Pathological Fractures & Musculoskeletal & Conn Tiss Malig	M	7,158	-0.027 to -0.035	0.901	79.2%
	141 Syncope & Collapse w CC	M	19,300	-0.043 to -0.056	0.901	80.2%
	524 Transient Ischemia	M	12,296	-0.036 to -0.047	0.897	80.8%
✓	120 Other Circulatory System O.R. Procedures	S	9,195	-0.026 to -0.034	0.896	81.3%
	316 Renal Failure	M	48,827	-0.035 to -0.046	0.894	83.9%
	202 Cirrhosis & Alcoholic Hepatitis	M	7,173	-0.032 to -0.042	0.893	84.3%
	403 Lymphoma & Non-Acute Leukemia w CC	M	9,099	-0.034 to -0.044	0.889	84.8%
	130 Peripheral Vascular Disorders w CC	M	20,951	-0.029 to -0.040	0.871	85.9%
	122 Circulatory Disorders w Ami w/o Major Comp, Discharged Alive	M	4,937	-0.045 to -0.061	0.863	86.2%
	134 Hypertension	M	4,540	-0.033 to -0.046	0.862	86.4%
✓	518 Percutaneous Cardiovasc Proc w/o Coronary Artery Stent Or AMI	S	6,106	-0.031 to -0.042	0.861	86.8%
	142 Syncope & Collapse w/o CC	M	4,366	-0.036 to -0.052	0.831	87.0%
	395 Red Blood Cell Disorders Age >17	M	27,027	-0.019 to -0.028	0.828	88.4%
✓	110 Major Cardiovascular Procedures w CC	S	7,493	-0.033 to -0.047	0.827	88.8%
	398 Reticuloendothelial & Immunity Disorders w CC	M	5,533	-0.037 to -0.054	0.816	89.1%
✓	466 Aftercare w/o History Of Malignancy As Secondary Dx	M	7,326	-0.052 to -0.076	0.810	89.5%

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	DRG FOR REHOSPITALIZATION	MS	Total Re-hospitalizations	Rate of change over time (k) (95% CI)	RSQ	Cum Pct of Rehs
	277 Cellulitis Age >17 w CC	M	16,973	-0.016 to -0.023	0.809	90.4%
	397 Coagulation Disorders	M	5,326	-0.028 to -0.042	0.804	90.7%
✓	001 Craniotomy Age >17 w CC	S	4,242	-0.035 to -0.053	0.782	91.0%
✓	478 Other Vascular Procedures w CC	S	23,688	-0.022 to -0.034	0.780	92.2%
	236 Fractures Of Hip & Pelvis	M	5,178	-0.021 to -0.032	0.777	92.5%
	415 O.R. Procedure For Infectious & Parasitic Diseases	S	18,406	-0.028 to -0.043	0.767	93.5%
✓	517 Percutaneous Cardiovascular Proc w Non-Drug Eluting Stent w/o AMI	S	7,924	-0.029 to -0.045	0.756	93.9%
✓	109 Coronary Bypass w/o Cardiac Cath	S	7,663	-0.042 to -0.068	0.726	94.3%
✓	515 Cardiac Defibrillator Implant w/o Cardiac Cath	S	4,492	-0.018 to -0.032	0.652	94.6%
✓	105 Cardiac Valve&Other Major Cardiothoracic Proc w/o Cardiac Cath	S	5,400	-0.023 to -0.046	0.580	94.8%
✓	527 Percutaneous Cardiovascular Proc w Drug-Eluting Stent w/o Ami	S	21,607	-0.017 to -0.034	0.575	96.0%
✓	209 Major Joint & Limb Reattachment Procedures Of Lower Extremity	S	15,106	-0.009 to -0.019	0.554	96.8%
✓	315 Other Kidney & Urinary Tract Procedures	S	7,416	-0.012 to -0.027	0.510	97.2%
	271 Skin Ulcers	M	4,267	-0.008 to -0.019	0.475	97.4%
✓	075 Major Chest Procedures	S	5,669	-0.010 to -0.024	0.449	97.7%
✓	113 Amputation For Circ System Disorders Except Upper Limb & Toe	S	10,859	-0.006 to -0.022	0.299	98.3%
✓	336 Transurethral Prostatectomy w CC	S	4,371	-0.004 to -0.023	0.231	98.5%
✓	410 Chemotherapy w/o Acute Leukemia As Secondary Dx	M	17,363	0.062 to 0.005	0.173	99.5%
✓	533 Extracranial Procedures w CC	S	5,373	0.002 to -0.014	0.085	99.8%
✓	263 Skin Graft &/Or Debrid For Skn Ulcer Or Cellulitis w CC	S	4,477	0.009 to -0.008	0.000	100.0%

✓ indicates DRG judged to have frequent planned admissions

MS indicates whether DRG is medical (M) or surgical (S)

RSQ is the R-Square statistic for how well the observed distribution fits the model

Cum Pct of Rehs is the cumulative percent of 30-day rehospitalizations in the 100 DRGs accounting for most of rehospitalizations.

Cells with grey background were considered important in deciding that a DRG probably included a substantial number of planned rehospitalizations.