

Supplementary Online Content

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

eTable 1. ICD-9-CM Codes Used to Define the Index Hospital Admission

Index event	ICD-9 codes (principal discharge diagnosis)
Ruptured Abdominal Aortic Aneurysm	441.3, 441.5, 441.6
Acute Myocardial Infarction	410.0, 410.01, 410.11, 410.21, 410.31, 410.41, 410.51, 410.61
Aortic Dissection	441.0, 441.00, 441.01, 441.03, 441.1, 441.6
Stroke	433.01, 433.11, 433.21, 433.31, 433.81, 433.91, 434.01, 434.11, 434.91, 436
Subarachnoid Hemorrhage	430

Note: Diagnoses codes were chosen to ensure that index hospitalizations represented true acute events. Those considered to be potentially nonspecific (e.g. 410.81—AMI NEC, and 410.91—AMI NOS) were excluded.

Sensitivity Analyses

eTables 2-4 show how results change with different methodological choices. These results can be compared to the primary study results summarized in table 2.

eTable 2. Effect of Excluding Recent Hospitalizations

	Index patients (N)	Observed ED discharges (N)	Expected ED discharges (N)	Potential diagnostic opportunities missed (% , 95% CI)
AAA	16,681	1,241	733	3.0% [2.4% -3.4%]
AMI	286,503	20,104	14,094	2.1% [1.9% -2.2%]
CVA	1,083,270	111,693	68,572	3.8% [3.8% -3.9%]
DIS	18,186	1,917	1,152	4.0% [3.5% -4.6%]
SAH	35,059	3,364	2,102	3.5% [3.1% -3.9%]

eTable 2 shows the effect of case-wise exclusion of patients discharged from any inpatient facility within 30 days of their index hospital admission, and (to avoid resulting bias) also excluding ED discharges that were preceded by any inpatient discharge within the prior 30 days.

eTable 3. Effect of Excluding Discharges After Observation Admissions

	Index patients (N)	Observed ED discharges (N)	Expected ED discharges (N)	Potential diagnostic opportunities missed (% , 95% CI)
AAA	17,963	1,482	873	3.3% [2.8% -3.8%]
AMI	304,980	22,876	16,695	2.0% [1.9% -2.1%]
CVA	1,181,648	127,954	82,586	3.7% [3.6% -3.8%]
DIS	19,675	2,138	1,393	3.6% [3.1% -4.2%]
SAH	37,674	3,867	2,577	3.3% [3.0% -3.7%]

eTable 3. In the primary analysis, we counted ED visits that ended in discharge home from an observation unit as ED discharges. eTable 3 shows the effect of treating these ED visits as neutral—counting them neither as discharges nor hospital admissions.

eTable 4. Effect of Varying Duration of “Pre-admission Window”

	INDEX PATIENTS (N)	ED DISCHARGES (N)					
		<u>Days 1-30</u>		<u>Days 1-45</u>		<u>Days 1-60</u>	
		Observed	Expected	Observed	Expected	Observed	Expected
AAA	17,963	1,279	663	1,603	970	1,936	1,259
AMI	304,980	19,160	12,496	25,622	18,483	31,925	24,304
CVA	1,181,648	109,105	63,209	142,743	92,348	174,821	120,330
DIS	19,675	1,913	1,071	2,482	1,565	3,045	2,023
SAH	37,674	3,237	1,949	4,245	2,871	5,176	3,816
		ESTIMATES (% Opportunities Missed)					
		<u>30-day window</u>		<u>45-day window</u>		<u>60-day window</u>	
AAA	17,963	3.3% [2.9% -3.7%]		3.4% [2.9% -4.0%]		3.6% [3.0% -4.3%]	
AMI	304,980	2.1% [2.0% -2.2%]		2.3% [2.1% -2.4%]		2.4% [2.3% -2.6%]	
CVA	1,181,648	3.7% [3.7% -3.8%]		4.1% [4.0% -4.2%]		4.4% [4.3% -4.5%]	
DIS	19,675	4.1% [3.6% -4.6%]		4.5% [3.9% -5.1%]		4.9% [4.2% -5.7%]	
SAH	37,674	3.3% [3.0% -3.6%]		3.5% [3.1% -3.9%]		3.5% [3.0% -4.0%]	

eTable 4 shows the effect of changing the how far in advance of the index hospitalization to look for excess ED discharges. Estimates are given for 30 days, 45 days, and 60 days. For example, 30-day results fit the logistic model using data for 365 to 31 days prior to the index admission, and use the difference between the sum of observed and expected ED discharges for the 30 days immediately preceding admission. The 45-day results are the same as those given in Table 2 of the main text.

In general, shorter windows (e.g. 30-days vs. 45 days) would be expected to increase the estimated “baseline rate of ED discharges” (since visits previously counted as “excess” would tend to steepen the regression line), and reduce the missed diagnosis rate to some degree. The converse would be true for longer windows.

eTable 5. Discharge Diagnoses Associated with Unrecognized Emergencies

Abdominal Aortic Aneurysm			
Diagnoses in greatest excess (observed-expected)	Observed	Expected	Incidence Rate Ratio [95% CI]
Abdominal pain, unspecified site	74	11.0	6.7 [4.8,9.4]
Lumbago	72	9.8	7.3 [5.2,10.3]

Abdominal pain, other specified site	59	8.6	6.9 [4.7,10.0]
Constipation, unspecified	55	11.3	4.9 [3.4,7.0]
Urinary tract infection, site not specified	62	21.7	2.9 [2.1,3.9]
Backache, unspecified	38	5.5	6.9 [4.3,11.1]
Obstructive chronic bronchitis with (acute) exacerbation	40	20.0	2.0 [1.4,2.9]
Syncope and collapse	33	15.9	2.1 [1.4,3.1]
Chest pain, unspecified	37	21.8	1.7 [1.2,2.4]
Sprain of lumbar	16	2.4	6.7 [3.2,14.1]
Pain in joint, pelvic region and thigh	17	5.2	3.3 [1.7,5.9]
Pneumonia, organism unspecified	22	10.1	2.2 [1.3,3.5]
Sciatica	12	1.3	9.5 [3.7,25.5]
Abdominal pain, right lower quadrant	12	1.7	7.1 [2.9,17.3]
Abdominal pain, left lower quadrant	13	2.7	4.9 [2.2,10.4]
Shortness of breath	14	3.5	4.0 [1.9,8.0]
Chronic airway obstruction, not elsewhere classified	14	4.2	3.3 [1.6,6.5]
Other malaise and fatigue	22	12.4	1.8 [1.1,2.9]
Nausea with vomiting	13	4.2	3.1 [1.5,6.1]
Open wound of forearm, without mention of complication	14	5.5	2.6 [1.3,4.8]
Diagnoses with highest incident rate ratios (observed/expected)			
Lumbago	72	9.8	7.3 [5.2 , 10.3]
Abdominal pain, unspecified site	74	11.0	6.7 [4.8 , 9.4]
Abdominal pain, other specified site	59	8.6	6.9 [4.7 , 10.0]
Backache, unspecified	38	5.5	6.9 [4.3 , 11.1]
Sciatica	12	1.3	9.5 [3.7 , 25.5]
Constipation, unspecified	55	11.3	4.9 [3.4 , 7.0]
Sprain of lumbar	16	2.4	6.7 [3.2 , 14.1]
Abdominal pain, right lower quadrant	12	1.7	7.1 [2.9 , 17.3]
Abdominal pain, generalized	8	0.8	9.5 [2.9 , 33.2]
Abdominal pain, left lower quadrant	13	2.7	4.9 [2.2 , 10.4]
Closed fracture of lumbar vertebra without mention of spinal cord injury	6	0.7	8.5 [2.2 , 35.3]
Urinary tract infection, site not specified	62	21.7	2.9 [2.1 , 3.9]
Other chronic pain	8	1.4	5.7 [2.0 , 16.0]
Shortness of breath	14	3.5	4.0 [1.9 , 8.0]
Pain in joint, pelvic region and thigh	17	5.2	3.3 [1.7 , 5.9]
Chronic airway obstruction, not elsewhere classified	14	4.2	3.3 [1.6 , 6.5]
Obstructive chronic bronchitis with acute bronchitis	11	3.0	3.7 [1.6 , 8.1]
Closed fracture of one rib	7	1.4	5.0 [1.6 , 14.5]
Vomiting alone	10	2.7	3.7 [1.6 , 8.5]
Nausea with vomiting	13	4.2	3.1 [1.5 , 6.1]

Acute Myocardial Infarction			
Diagnoses in greatest excess (observed-expected)	Observed	Expected	Incidence Rate Ratio [95% CI]
Chest pain, unspecified	1871	676.7	2.8 [2.6,2.9]
Other chest pain	1256	512.2	2.5 [2.3,2.6]
Urinary tract infection, site not specified	681	434.0	1.6 [1.4,1.7]
Esophageal reflux	233	48.9	4.8 [4.0,5.6]
Obstructive chronic bronchitis with (acute) exacerbation	403	244.4	1.6 [1.5,1.8]
Congestive heart failure, unspecified	297	147.9	2.0 [1.8,2.3]
Epistaxis	299	164.4	1.8 [1.6,2.1]
Pneumonia, organism unspecified	302	173.1	1.7 [1.5,2.0]
Painful respiration	261	132.6	2.0 [1.7,2.3]
Other malaise and fatigue	348	222.3	1.6 [1.4,1.8]
Dehydration	223	108.8	2.0 [1.8,2.4]
Syncope and collapse	397	291.9	1.4 [1.2,1.5]
Abdominal pain, unspecified site	389	287.0	1.4 [1.2,1.5]
Other and unspecified angina pectoris	144	45.0	3.2 [2.6,3.9]
Other respiratory abnormalities	228	129.1	1.8 [1.5,2.0]
Acute bronchitis	301	205.6	1.5 [1.3,1.7]
Retention of urine, unspecified	241	147.8	1.6 [1.4,1.9]
Intermediate coronary syndrome	109	23.2	4.7 [3.7,6.0]
Other and unspecified noninfectious gastroenteritis and colitis	224	137.5	1.6 [1.4,1.9]
Constipation, unspecified	256	169.7	1.5 [1.3,1.7]
Diagnoses with highest incident rate ratios (observed/expected)			
Esophageal reflux	233	48.9	4.8 [4.0,5.6]
Intermediate coronary syndrome	109	23.2	4.7 [3.7,6.0]
Dyspepsia and other specified disorders of function of stomach	36	8.0	4.5 [2.9,6.9]
Swelling, mass, or lump in chest	14	2.4	5.9 [2.7,12.6]
Chest pain, unspecified	1871	676.7	2.8 [2.6,2.9]
Other and unspecified angina pectoris	144	45.0	3.2 [2.6,3.9]
Precordial pain	110	35.3	3.1 [2.5,3.9]
Spondylosis of unspecified site, without mention of myelopathy	10	1.5	6.5 [2.5,16.8]
Unspecified gastritis and gastroduodenitis, w/o mention of hemorrhage	100	31.8	3.1 [2.5,4.0]
Acute respiratory failure	11	1.8	6.0 [2.4,14.6]
Mechanical complication of colostomy and enterostomy	7	0.8	8.3 [2.4,29.9]
Other chest pain	1256	512.2	2.5 [2.3,2.6]
Malignant neoplasm of bronchus and lung, unspecified	16	3.9	4.1 [2.1,7.8]
Esophagitis, unspecified	17	4.4	3.9 [2.0,7.3]
Pain in thoracic spine	51	18.0	2.8 [2.0,3.9]
Pressure ulcer, buttock	10	2.1	4.7 [1.9,11.3]
Malignant neoplasm of pancreas, part unspecified	6	0.8	7.1 [1.9,26.6]
Coronary atherosclerosis of native coronary artery	112	47.4	2.4 [1.9,2.9]
Coronary atherosclerosis of unspecified type of vessel, native or graft	65	25.7	2.5 [1.9,3.4]
Congestive heart failure, unspecified	297	147.9	2.0 [1.8,2.3]

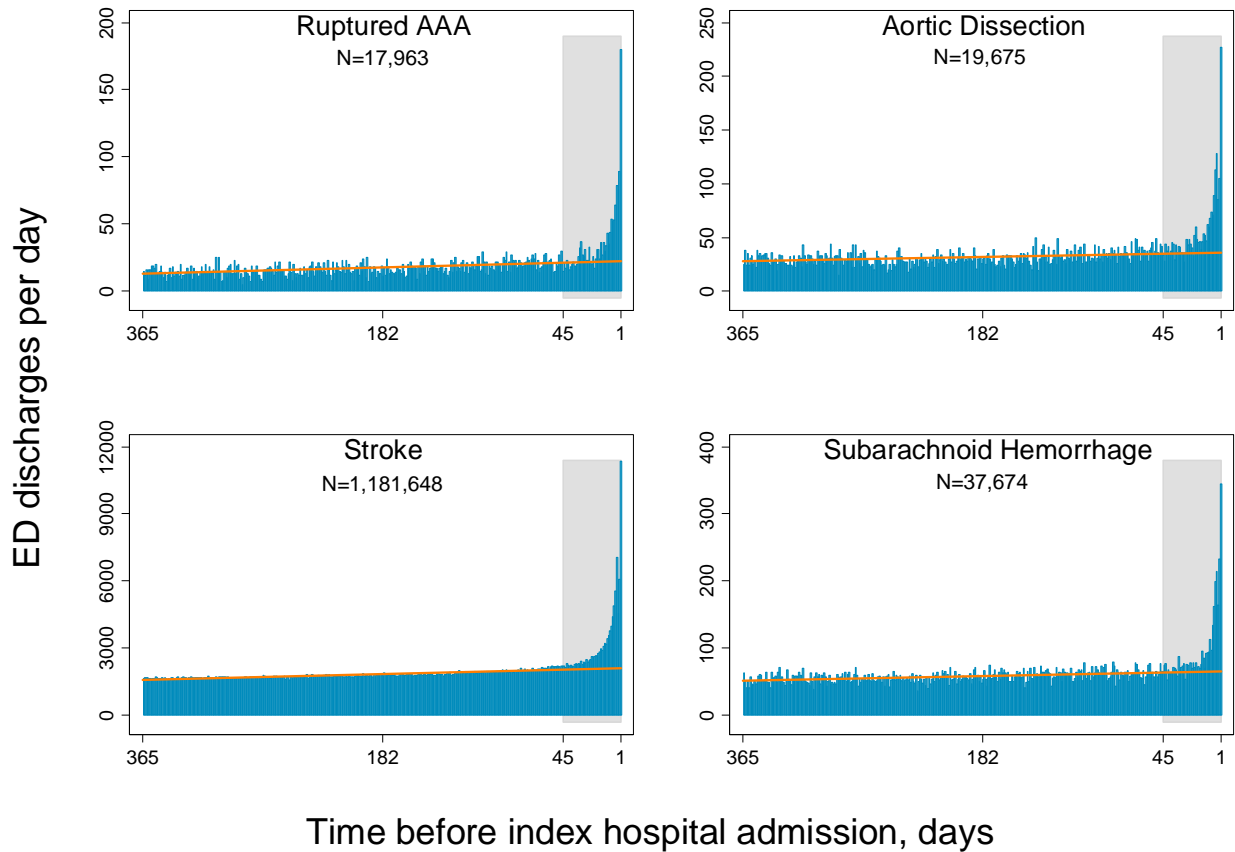
Aortic Dissection			
Diagnoses in greatest excess (observed-expected)	Observed	Expected	Incidence Rate Ratio [95% CI]
Chest pain, unspecified	201	51.3	3.9 [3.3,4.7]
Other chest pain	155	41.5	3.7 [3.1,4.6]
Backache, unspecified	60	13.9	4.3 [3.1,6.0]
Lumbago	59	22.6	2.6 [1.9,3.5]
Abdominal pain, unspecified site	61	24.9	2.5 [1.8,3.3]
Painful respiration	35	12.9	2.7 [1.8,4.0]
Abdominal pain, other specified site	36	13.8	2.6 [1.7,3.9]
Other malaise and fatigue	44	21.9	2.0 [1.4,2.8]
Abdominal pain, epigastric	30	8.9	3.4 [2.1,5.3]
Pneumonia, organism unspecified	34	13.1	2.6 [1.7,3.9]
Unspecified essential hypertension	59	37.8	1.6 [1.2,2.1]
Constipation, unspecified	31	11.4	2.7 [1.7,4.2]
Congestive heart failure, unspecified	32	12.5	2.6 [1.7,3.9]
Obstructive chronic bronchitis with (acute) exacerbation	35	17.7	2.0 [1.3,2.9]
Other respiratory abnormalities	27	11.3	2.4 [1.5,3.8]
Syncope and collapse	37	22.4	1.7 [1.1,2.4]
Headache	40	25.7	1.6 [1.1,2.2]
Pain in thoracic spine	14	1.8	7.7 [3.3,17.7]
Atrial fibrillation	25	13.1	1.9 [1.2,3.0]
Other acute pain	15	4.4	3.4 [1.7,6.6]
Diagnoses with highest incident rate ratios (observed/expected)			
Pain in thoracic spine	14	1.8	7.7 [3.3,17.7]
Chest pain, unspecified	201	51.3	3.9 [3.3,4.7]
Backache, unspecified	60	13.9	4.3 [3.1,6.0]
Other chest pain	155	41.5	3.7 [3.1,4.6]
Unspecified pleural effusion	9	1.1	8.0 [2.7,23.8]
Sprain of thoracic	10	1.7	5.9 [2.3,15.0]
Angioneurotic edema, not elsewhere classified	10	1.8	5.5 [2.1,13.5]
Abdominal pain, epigastric	30	8.9	3.4 [2.1,5.3]
Lumbago	59	22.6	2.6 [1.9,3.5]
Abdominal pain, unspecified site	61	24.9	2.5 [1.8,3.3]
Painful respiration	35	12.9	2.7 [1.8,4.0]
Constipation, unspecified	31	11.4	2.7 [1.7,4.2]
Abdominal pain, other specified site	36	13.8	2.6 [1.7,3.9]
Other acute pain	15	4.4	3.4 [1.7,6.6]
Pneumonia, organism unspecified	34	13.1	2.6 [1.7,3.9]
Tietze's disease	6	1.0	6.1 [1.7,21.2]
Esophageal reflux	12	3.2	3.7 [1.7,7.8]
Congestive heart failure, unspecified	32	12.5	2.6 [1.7,3.9]
Other respiratory abnormalities	27	11.3	2.4 [1.5,3.8]
Sprain of lumbosacral (joint) (ligament)	5	0.8	5.9 [1.4,23.3]

Stroke			
Diagnoses in greatest excess (observed-expected)	Observed	Expected	Incidence Rate Ratio [95% CI]
Unspecified transient cerebral ischemia	5606	1074.2	5.2 [5.0,5.4]
Other malaise and fatigue	4956	1587.0	3.1 [3.0,3.2]
Dizziness and giddiness	4464	1662.0	2.7 [2.6,2.8]
Urinary tract infection, site not specified	5046	2522.7	2.0 [1.9,2.1]
Unspecified essential hypertension	3612	1710.4	2.1 [2.0,2.2]
Headache	3239	1390.8	2.3 [2.2,2.4]
Altered mental status	1956	611.0	3.2 [3.0,3.4]
Syncope and collapse	3029	1773.4	1.7 [1.6,1.8]
Disturbance of skin sensation	1422	348.5	4.1 [3.8,4.4]
Dehydration	1662	684.4	2.4 [2.3,2.6]
Chest pain, unspecified	3277	2419.7	1.4 [1.3,1.4]
Atrial fibrillation	1541	738.0	2.1 [2.0,2.2]
Congestive heart failure, unspecified	1804	1009.4	1.8 [1.7,1.9]
Head injury, unspecified	1736	1017.3	1.7 [1.6,1.8]
Abdominal pain, unspecified site	1963	1262.8	1.6 [1.5,1.6]
Contusion of face, scalp, and neck except eye(s)	1798	1103.8	1.6 [1.5,1.7]
Epistaxis	1622	1014.3	1.6 [1.5,1.7]
Nausea with vomiting	1190	589.1	2.0 [1.9,2.2]
Other musculoskeletal symptoms referable to limbs	680	106.0	6.4 [5.8,7.1]
Pain in limb	1613	1060.3	1.5 [1.4,1.6]
Diagnoses with highest incident rate ratios (observed/expected)			
Homonymous bilateral field defects	27	1.7	16.0 [7.8,34.7]
Other musculoskeletal symptoms referable to limbs	680	106.0	6.4 [5.8,7.1]
Other speech disturbance	249	36.1	6.9 [5.8,8.2]
Unspecified transient cerebral ischemia	5606	1074.2	5.2 [5.0,5.4]
Facial weakness	138	23.2	5.9 [4.7,7.5]
Dysarthria	54	9.0	6.0 [4.1,8.8]
Hemiplegia, unspecified, affecting unspecified side	34	5.1	6.7 [4.1,11.0]
Wrist drop (acquired)	13	1.3	10.3 [4.1,27.2]
Reactive confusion	28	4.1	6.9 [3.9,12.0]
Other localized visual field defect	9	0.7	12.8 [3.9,48.6]
Disturbance of skin sensation	1422	348.5	4.1 [3.8,4.4]
Central retinal artery occlusion	23	3.2	7.1 [3.8,13.3]
Aphasia	124	26.0	4.8 [3.8,6.0]
Muscle weakness (generalized)	268	62.3	4.3 [3.7,5.0]
Occlusion and stenosis of carotid artery without mention of cerebral infarction	90	18.6	4.8 [3.7,6.4]
Unspecified visual disturbance	134	29.7	4.5 [3.6,5.6]
Other specified visual disturbances	233	55.1	4.2 [3.6,5.0]
Malignant neoplasm of ovary	14	1.7	8.3 [3.6,19.6]
Other symptoms involving nervous and musculoskeletal systems	60	12.2	4.9 [3.5,6.9]
Mononeuritis of upper limb, unspecified	85	18.6	4.6 [3.4,6.1]

Subarachnoid Hemorrhage			
Diagnoses in greatest excess (observed-expected)	Observed	Expected	Incidence Rate Ratio [95% CI]
Headache	351	61.5	5.7 [4.9,6.6]
Unspecified transient cerebral ischemia	85	24.6	3.5 [2.6,4.5]
Unspecified essential hypertension	90	43.5	2.1 [1.6,2.6]
Other malaise and fatigue	78	35.6	2.2 [1.7,2.8]
Cervicalgia	50	12.2	4.1 [2.8,5.9]
Dizziness and giddiness	85	51.0	1.7 [1.3,2.1]
Vomiting alone	44	13.1	3.4 [2.3,4.9]
Other and unspecified noninfectious gastroenteritis and colitis	49	18.6	2.6 [1.9,3.7]
Urinary tract infection, site not specified	97	67.9	1.4 [1.1,1.8]
Sprain of neck	40	13.4	3.0 [2.0,4.4]
Altered mental status	42	15.0	2.8 [1.9,4.0]
Nausea with vomiting	45	18.3	2.5 [1.7,3.5]
Head injury, unspecified	56	29.0	1.9 [1.4,2.6]
Lumbago	60	34.0	1.8 [1.3,2.3]
Syncope and collapse	75	49.4	1.5 [1.2,2.0]
Abdominal pain, unspecified site	64	38.8	1.6 [1.2,2.2]
Migraine, unspecified, without mention of intractable migraine without mention of status migrainosus	48	23.6	2.0 [1.4,2.8]
Backache, unspecified	43	21.7	2.0 [1.4,2.8]
Disturbance of skin sensation	28	9.4	3.0 [1.8,4.7]
Unspecified viral infection	22	4.5	4.9 [2.7,8.7]
Diagnoses with highest incident rate ratios (observed/expected)			
Headache	351	61.5	5.7 [4.9,6.6]
Tension headache	14	1.3	11.1 [4.5,29.0]
Cerebral aneurysm, nonruptured	14	2.1	6.6 [3.0,14.7]
Cervicalgia	50	12.2	4.1 [2.8,5.9]
Unspecified viral infection	22	4.5	4.9 [2.7,8.7]
Unspecified transient cerebral ischemia	85	24.6	3.5 [2.6,4.5]
Vomiting alone	44	13.1	3.4 [2.3,4.9]
Sprain of neck	40	13.4	3.0 [2.0,4.4]
Bell's palsy	7	1.1	6.2 [1.9,19.6]
Altered mental status	42	15.0	2.8 [1.9,4.0]
Other and unspecified noninfectious gastroenteritis and colitis	49	18.6	2.6 [1.9,3.7]
Disturbance of skin sensation	28	9.4	3.0 [1.8,4.7]
Nausea with vomiting	45	18.3	2.5 [1.7,3.5]
Other malaise and fatigue	78	35.6	2.2 [1.7,2.8]
Unspecified essential hypertension	90	43.5	2.1 [1.6,2.6]
Angioneurotic edema, not elsewhere classified	13	4.1	3.2 [1.5,6.3]
Other musculoskeletal symptoms referable to limbs	7	1.5	4.5 [1.5,12.8]
Dementia, unspecified, without behavioral disturbance	7	1.5	4.5 [1.5,12.8]
Contusion of hip	32	14.1	2.3 [1.5,3.4]
Spasm of muscle	8	2.0	4.1 [1.5,10.4]

eTable 5 compares the relative incidence of principal discharge diagnoses in the 45 days preceding the index hospital admission to the incidence in the preceding 320 days. For each diagnosis, the number of ED discharges observed within 45 days of the index admission is shown, together with the number expected, using the average incidence in the preceding 320 days (i.e. $N_{\text{expected}} = (N_{\text{observed, days 46 to 365}}) * 45 / 320$). For each of the five types of cardiovascular emergencies, the 20 discharge diagnoses associated with the greatest number of excess visits (i.e. the greatest difference between observed and expected), representing the most common discharge diagnoses given to patients with an unrecognized diagnosis, along with the 20 diagnoses associated with the highest incident rate ratios (i.e. the greatest ratio of observed to expected, determined by the lower bound of the 95% confidence interval), representing the discharge diagnoses with the highest positive predictive value.

eFigure. Distribution of ED discharges in the year preceding index hospital admission



eFigure. This graph shows the timing of ED discharges among patients ultimately diagnosed with ruptured AAA, aortic dissection, stroke, and subarachnoid hemorrhage, over the 365 days preceding their index hospital admission. The height of each vertical bar represents the observed number of daily ED discharges, and the regression line represents the number expected. The logistic regression was fitted using the unshaded portion of the graph (i.e. days 365-46). The number of unrecognized diagnostic opportunities is represented as the net difference between the number of ED discharges observed (vertical bars) and the number expected (regression line) during the 45 days preceding the index hospital admission (shaded area). eFigure 1 (online supplement) provides a similar illustration of the other four conditions. Figure 1 in the main text provides a similar illustration for acute myocardial infarction.