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ORIGINAL RESEARCH

Off Hours and Weekend Admissions to Danish Medical Departments: Admission Rates and 30-Day Mortality for 20 Common Medical Conditions

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Abstract

Objectives: Knowledge on the combined weekly and diurnal variation in timing of admissions and mortality rates for acute medical patients is limited. The aim of the study was to examine hospital admission rates and mortality rates for patients with common medical conditions according to time of admission.

Design: Nationwide population-based cohort study.

Setting: Population of Denmark.

Participants: Using the Danish National Registry of Patients (DNRP) covering all Danish hospitals, we identified all adults (>=15 years) with the first acute admission to a medical department in Denmark during 2010. Readmissions and transfers were excluded.

Primary and secondary outcome measures: Hourly admission rates and age- and sex-standardized 30-day mortality rates comparing weekday office hours, weekday off hours, weekend daytime hours, and weekend nighttime hours.

Results: A total of 174,192 acute medical patients were included in the study. The admission rate during weekday office hours was 38.7 (95% Confidence Interval (CI) 38.4-38.9) patients per hour, and corresponding figures were 13.3 (95% CI 13.2-13.5) during weekday off hours, 19.8 (95% CI 19.6-20.1) during weekend daytime hours, and 7.9 (95% CI 7.8-8.0) during weekend nighttime hours. Admission rates varied considerably between medical conditions. The proportion admitted through the emergency room more than doubled outside office hours. The age- and sex-

standardized 30-day mortality rate was 5.1% (95% CI 5.0-5.3%) for patients admitted during weekday office hours, 5.7% (95%CI 5.5-6.0%) for patients admitted during weekday off hours, 6.4% (95%CI 6.1-6.7%) for patients admitted during weekend daytime hours, and 6.3% (95%CI 5.9-6.8%) for patients admitted during weekend nighttime hours. For 17 out of the 20 medical conditions examined, weekend admission was associated with higher mortality than weekday admission.

Conclusions: While timing of first-time admissions varied, weekend admissions were associated with the highest mortality for the majority of the conditions examined.

ARTICLE SUMMARY

Strengths and limitations of this study

- This study is the first to analyze hourly admission rates and mortality rates associated with time of admission in 20 common conditions among acute medical patients in a population-based design
- We provide a subtle categorization of time of admission including both weekday office hours, weekday off hours, weekend daytime hours and weekend nighttime hours
- Our study lacked clinical data on severity of disease and staffing level, but included information on the proportion admitted to intensive care units according to time of admission.

INTRODUCTION

Acute hospital admission rate decreases during weekend, but an admission during weekend has been associated with higher in-hospital mortality, an association termed "the weekend effect".[1-16] The weekend effect has been observed among acutely hospitalized patients in differing healthcare systems, including Canada, the US, and Australia, as well as in European countries. Understanding the higher short-term mortality associated with weekend admissions is important both for clinicians and healthcare planners. Two possible explanations for the weekend effect are the changes in the availability of specialized care or changes in patient characteristics, *e.g.* disease severity.[17]

A more subtle categorization of time of admission in patients admitted during weekday office hours and off hours, as well as daytime hours and nighttime hours during the weekend may clarify important differences in patient characteristics. Furthermore, admission rates for common medical conditions in these time periods may serve as a proxy of the changes in referral threshold and together with mortality rates add to the understanding of the weekend effect. Variation in timing of admission and mortality rates for common medical conditions has to our best knowledge not previously been examined. Previous studies examining "off hours" and mortality have primarily investigated "off hours" as the time outside regular hours/office hours, not distinguishing between "Office" and "Off" hours during weekdays, as well as between daytime and nighttime hours of the weekend.[8,9]

We therefore examined the hourly admission rates and 30-day mortality rates for patients with 20 common medical conditions comparing weekday office hours, weekday off hours, weekend daytime hours, and weekend nighttime hours in a cohort of acute medical patients with their first admission to departments of medicine during 2010 in Denmark.

METHODS

Study design and setting

In this register-based cohort study, we identified all acute hospital admissions to medical departments in Denmark between 1 January and 31 December 2010, as recorded in the Danish National Registry of Patients (DNRP). The DNRP is a central medical registry covering both public and private hospitals and contains information on all hospital admissions to non-psychiatric hospitals since 1977 and on all hospital contacts with emergency rooms and hospital specialist clinics since 1995. In Denmark, the private hospitals account for less than 1% of the total number of beds and they do not provide acute care.[18] General practitioners (GPs) has a key role in referring patients to the hospital departments since virtually all Danish residents are affiliated with a personal GP. Outside regular office hours, GPs serve the patients from central regional clinics providing both phone service and consultation. In an emergency situation, the patients can present on their own or by ambulance to the emergency room. Denmark has a free, tax-funded health care system, which assures that all residents (5,534,738 million persons as of 1 January 2010) in both rural and urban

areas have unrestricted and equal access to GPs and to specialist care in hospitals.[19,20]

Study population

The cohort, which included all patients with their first acute admission to medical departments in Denmark between 1 January and 31 December 2010, has previously been described. [21] For this present study, we excluded patients with an inpatient stay in a hospital department within the preceding 30 days or earlier on the day of admission.

Time of admission

Time of admission was defined as weekday office hours, weekday off hours, weekend daytime hours, and weekend nighttime hours. Public holidays, *e.g.* Easter and Christmas were considered weekend days. In 2010, 26.8% of the total number of hours was defined as weekday office hours (Monday to Friday from 8.00 am to 4.59 pm), 38.7% as weekday off hours (Monday to Friday from 5.00 pm to 7.59 am, except Friday evening from 10.00 pm-11.59 pm and Monday night from 0.00 pm to 7.59 am), 15.4% as weekend daytime hours (Saturday and Sunday from 9.00 am to 9.59 pm), and 19.0% as weekend nighttime hours (Saturday and Sunday from 10.00 pm to 11.59 pm and 0.00 am-8.59 am plus Friday evening from 10.00-11.59 pm and Monday night from 0.00 am to 7.59 am). Admission rates were computed hourly according to time of admission.

Mortality

Each Danish resident is assigned a unique personal identification number (CPR number) at birth or upon immigration by the Danish Civil Registration System (CRS).[22] Information on all-cause mortality within 30 days following the index date was captured by linking patients' CPR number to the CRS. The CRS was established in 1968 to collect and maintain information on vital status, marital status, residency, and migration for all residents of Denmark. The CRS thus contains complete up-to-date data on the vital status of all patients in our study. Patients were followed from their index date until death from any cause, emigration, or 30 days after the index date, whichever came first.

Patient characteristics

The DNRP provided the unique code for each hospital and department, admission type (*i.e*. acute), date of admission (*index date*), hour and minute of admission (00.00-23.59 hours), source of admission (hospital specialist clinic, emergency room, or direct referral), codes for Intensive Care Unit (ICU) admission, date of discharge, and discharge diagnoses, with one primary diagnosis reflecting the reason for admission and up to 19 secondary diagnoses, indicating additional chronic or acute diseases. Diagnoses were coded according to *the International Classification of Diseases*, version 10 (ICD-10).

By tabulation of the primary ICD-10 diagnoses assigned after the index admission, considered to be the main reason for admission, we identified 20 common conditions among acute medical patients, *i.e*. pneumonia, erysipelas, bacteremia/sepsis, urinary

tract infection, anemia, diabetes, dehydration, alcohol intoxication, transient ischemic attack, angina, acute myocardial infarction, atrial fibrillation, heart failure, hypertension, stroke, chronic obstructive pulmonary disorder, respiratory failure, gastroenteritis, syncope, and suspected acute myocardial infarction (ICD-10 codes provided in Appendix, Table S1).

To capture clinically important morbidity, data on the 19 conditions included in the Charlson Comorbidity Index (CCI) were obtained from the DNRP for the five years preceding the index date (ICD-10 codes provided in Appendix, Table S2). The CCI score was divided in low (score of 0), moderate (score of 1-2), and high (score of 3 or higher). From CRS, data on marital status (married, never married, divorced, widowed, and unknown) were provided. We computed length of hospital stay as time from the index date to final hospital discharge, including in-hospital and inter-hospital transfers, except those occurring more than one day after a preceding discharge as they were considered readmissions rather than transfers.

Statistical analysis

We classified patients as admitted during weekday office hours, weekday off hours, weekend daytime hours, and weekend nighttime hours, and characterized them according to patient characteristics. The hourly admission rates and the 30-day mortality rates were computed for the common medical conditions according to time of admission. We standardized 30-day mortality to the age- and gender-distribution of patients admitted during weekday office hours using direct standardization.[23] We also reported the proportions of patients admitted to an ICU within three days

following the index date and during the whole hospital stay. An ICU admission serves as a proxy of both the availability of an ICU bed but also for the severity of the disease.

In a subgroup analysis, the admission rate, 30-day mortality rate, and ICU admissions during the four time periods were analyzed only among patients admitted through the emergency room. Data were analyzed with the statistical software package STATA (version 11, Stata Corp., College Station, Texas, USA). The study was approved by the Danish Data Protection Agency (record number 1-16-02-1-08). Because the study was based solely on data from administrative and medical databases, no further approval from the Ethics Committee was required.

RESULTS

Patient characteristics

A total of 264,265 patients with an acute first-time admission to medical departments in Denmark during 2010 were registered. After excluding patients without residency in Denmark (n=505) and patients with a hospital admission within the preceding 30 days or on the day of the index admission (n=89,568), 174,192 patients were included in the study. Of these patients, 50.4% (n=87,764) were admitted during weekday office hours, 24.9% (n=43,312) during weekday off hours, 16.7% (n=29,140) during weekend daytime hours, and 8.0% (n=13,976) during weekend nighttime hours. As shown in Table 1, patients admitted during weekday office hours tended to be older and had slightly higher CCI scores than patients admitted during other time periods. Weekend nighttime hours were the only time of admission when males constituted the highest proportion of patients (50.8%). No major differences among patients were observed

with regard to the individual CCI conditions. During weekday office hours, 15.1% were admitted through the emergency room, while 33.5% were admitted through the emergency room during weekday off hours. Similarly, weekend daytime and weekend nighttime hours were associated with a high rate of admissions through the emergency room (30.2% and 33.0%, respectively).

Table 1. Demographic and clinical characteristics of 174,192 patients with an acute admission to a department of medicine, by time of admission, Denmark, 2010.

	Weekday		Weekend	
	Office hours (8.00 am-4.59 pm)	Off hours (5.00 pm-7.59 am)	Day (9.00 am -9.59 pm)	Night (10.00 pm-8.59 am) plus Friday 10.00-11.59 pm and Monday 0.00-7.59 am
Overall	87,764 (50.4%)	43,312 (24.9%)	29,140 (16.7%)	13,976 (8.0%)
Age groups				
15-39	9,291 (10.6)	7,246 (16.7)	3,960 (13.6)	2,528 (18.1)
40-59	19,888 (22.7)	10,902 (25.2)	6,764 (23.2)	3,456 (24.7)
60-79	36,722 (41.8)	15,794 (36.5)	11,079 (38.0)	5,146 (36.8)
80+	21,863 (24.9)	9,370 (21.6)	7,337 (25.2)	2,846 (20.4)
Age, Median (years (IQR))	68 (54-79)	64 (47-78)	67 (51-80)	64 (46-77)
Gender				
Female	45,877 (52.3)	22,175 (51.2)	15,073 (51.7)	6,880 (49.2)
Male	41,887 (47.7)	21,1375 (48.8)	14,067 (48.3)	7,096 (50.8)
Charlson Comorbidity Index score				
0	49,384 (56.3)	25,710 (59.4)	16,647 (57.1)	8,055 (57.6)
1-2	27,302 (31.1)	12,687 (29.3)	8,996 (30.9)	4,267 (30.5)
3+	11,078 (12.6)	4,915 (11.4)	3,497 (12.0)	1,654 (11.8)
Presence of diseases included in the Charlson Comorbidity Index				
Myocardial infarction	3,246 (3.7)	1,658 (3.8)	1,117 (3.8)	590 (4.2)
Congestive heart failure	5,735 (6.5)	2,477 (5.7)	1,748 (6.0)	913 (6.5)
Peripheral vascular disease	4,683 (5.3)	1,926 (4.4)	1,388 (4.8)	686 (4.9)
Cerebrovascular disease	8,110 (9.2)	4,052 (9.3)	2,917 (10.0)	1,353 (9.8)
Dementia	1,920 (2.2)	1,013 (2.3)	769 (2.6)	296 (2.1)
Chronic pulmonary disease	9,934 (11.3)	4,758 (11.0)	3,296 (11.3)	1,691 (12.1)
Connective tissue disease	2,977 (3.4)	1,181 (2.7)	889 (3.1)	386 (2.8)
Ulcer disease	2,479 (2.8)	1,138 (2.6)	778 (2.7)	367 (2.6)
Mild liver disease	1,435 (1.6)	691 (1.6)	451 (1.6)	209 (1.5)
Diabetes without end-organ damage	7,154 (8.2)	3,362 (7.8)	2,268 (7.8)	1,099 (7.9)
Diabetes with end-organ damage	4,337 (4.9)	2,101 (4.9)	1,386 (4.8)	675 (4.8)
Hemiplegia	313 (0.4)	163 (0.4)	106 (0.4)	53 (0.4)
Moderate to severe renal disease	3,036 (3.5)	1,289 (3.0)	918 (3.2)	432 (3.1)
Non-metastatic solid tumor	7,555 (8.6)	3,157 (7.3)	2,393 (8.2)	1,032 (7.4)
Leukaemia	500 (0.6)	193 (0.5)	131 (0.5)	56 (0.4)
Lymphoma	874 (1.0)	354 (0.8)	270 (0.9)	107 (0.8)
Moderate to severe liver disease	511 (0.6)	202 (0.5)	159 (0.6)	85 (0.6)
Metastatic cancer	1,035 (1.2)	373 (0.9)	360 (1.2)	140 (1.0)
AIDS	152 (0.2)	85 (0.2)	50 (0.2)	23 (0.2)
Marital status				
Married	40,881 (46.6)	18,719 (43.2)	12,794 (43.9)	6,358 (45.5)
Never married	14,140 (16.1)	9,206 (21.3)	5,364 (18.4)	2,981 (21.3)
Divorced	12,414 (14.1)	6,486 (15.0)	4,230 (14.5)	2,064 (14.8)
Widowed	20,325 (23.2)	8,904 (20.6)	6,751 (23.2)	2,573 (18.4)
Unknown	4	0	1	0
Admission source				
Hospital outpatient specialist clinic	5,781 (6.6)	2,251 (5.2)	1,139 (3.9)	541 (3.9)
Emergency room	13,225 (15.1)	14,492 (33.5)	8,810 (30.2)	4,618 (33.0)
Other	69,438 (79.0)	27,343 (63.1)	19,610 (67.3)	8,997 (64.4)
Length of hospital stay [Median (days)]	3 (1-7)	2 (1-7)	3 (1-7)	3 (1-6)
Common medical conditions				
Pneumonia	5,886 (6.7)	2,797 (6.5)	2,197 (7.5)	978 (7.0)
Erysipelas	991 (1.1)	513 (1.2)	367 (1.3)	125 (0.9)
Bacteremia/Sepsis	1,201 (1.4)	759 (1.8)	563 (1.9)	238 (1.7)
Urinary tract infection	1,944 (2.2)	996 (2.3)	740 (2.5)	300 (2.2)
Anemia	2,384 (2.7)	417 (1.0)	266 (0.9)	93 (0.7)
Diabetes	1,540 (1.8)	507 (1.2)	326 (1.1)	158 (1.1)
Dehydration	2,073 (2.4)	953 (2.2)	697 (2.4)	213 (1.5)
Alcohol intoxication	989 (1.1)	994 (2.3)	556 (1.9)	388 (2.8)
Transient ischemic attack	1,380 (1.6)	811 (1.9)	609 (2.1)	200 (1.4)
Angina	2,191 (2.5)	1,000 (2.3)	616 (2.1)	408 (2.9)
Acute myocardial infarction	2,274 (2.6)	1,317 (3.0)	997 (3.4)	694 (5.0)

Atrial fibrillation	3,707 (4.2)	1,170 (2.7)	889 (3.1)	354 (2.5)
Heart failure	1,645 (1.9)	535 (1.2)	300 (1.0)	207 (1.5)
Hypertension	1,173 (1.3)	487 (1.1)	329 (1.1)	136 (1.0)
Stroke	3,187 (3.6)	1,587 (3.7)	1,407 (4.8)	515 (3.7)
Chronic obstructive pulmonary disorder	2,869 (3.3)	1,273 (2.9)	926 (3.2)	545 (3.9)
Respiratory failure	1,120 (1.3)	559 (1.3)	414 (1.4)	224 (1.6)
Gastroenteritis	1,179 (1.3)	612 (1.4)	466 (1.6)	231 (1.7)
Syncope	1,554 (1.8)	1,195 (2.8)	865 (3.0)	336 (2.4)
Suspected acute myocardial infarction	3,719 (4.2)	2,304 (5.3)	1,455 (5.0)	712 (5.1)
Other	44,758 (51.0)	22,526 (52.0)	14,155 (44.6)	6,921 (49.5)

Abbreviation: IQR= interquartile range

Weekend nighttime hours were associated with the highest proportion of patients admitted to an ICU within the first three days (4.4%) compared to weekend daytime hours (3.2%), weekday off hours (3.1%), and weekday office hours (2.0%) (Appendix, Table S3). For more than half of the individual medical conditions we examined, the highest risk of an ICU admission was associated with an admission during weekend nighttime hours. For all 20 medical conditions except respiratory failure, admission weekday office hours were associated with the lowest risk of an ICU admission.

Admission rates

The admission rate during weekday office hours was 38.7 (95% Confidence Intervals (CI) 38.4-38.9) patients per hour, and corresponding figures were 13.3 (95% CI 13.2-13.5) during weekday off hours, 19.8 (95% CI 19.6-20.1) during weekend daytime hours, and 7.9 (95% CI 7.8-8.0) during weekend nighttime hours (Table 2). Among the common medical conditions, pneumonia had the overall highest admission rate in all time periods. Anemia, diabetes, atrial fibrillation, and heart failure had the relatively largest decreases in admission rates from weekday office hours to the other time periods while a condition like alcohol intoxication was associated with a more stable admission rate across time periods. The medical conditions with the lowest admission rates during weekend nighttime hours were anemia, erysipelas, diabetes, and hypertension.

Table 2. Hourly admission rates for 20 common medical conditions by time of admission.

	Weekday		Weekend	
	Office hours (8.00 am-4.59 pm)	Off hours (5.00 pm-7.59 am)	Day (9.00 am-9.59 pm)	Night (10.00 pm-8.59 am) plus Friday 10.00-11.59 pm and Monday 0.00-7.59 am
Overall	38.7 (38.4-38.9)	13.3 (13.2-13.5)	19.8 (19.6-20.1)	7.9 (7.8-8.0)
Common medical conditions				
Infectious diseases				
Pneumonia	2.60 (2.53-2.66)	0.86 (0.83-0.89)	1.50 (1.43-1.56)	0.55 (0.52-0.59)
Erysipelas	0.44 (0.41-0.47)	0.16 (0.14-0.17)	0.25 (0.22-0.28)	0.07 (0.06-0.08)
Bacteremia/septicemia	0.53 (0.50-0.56)	0.23 (0.22-0.25)	0.38 (0.35-0.42)	0.13 (0.12-0.15)
Urinary Tract Infection	0.86 (0.82-0.90)	0.31 (0.29-0.33)	0.50 (0.47-0.54)	0.17 (0.15-0.19)
Hematological Diseases				
Anemia	1.05 (1.01-1.09)	0.13 (0.12-0.14)	0.18 (0.16-0.20)	0.05 (0.04-0.06)
Endocrine and nutritional disease				
Diabetes	0.68 (0.65-0.71)	0.16 (0.14-0.17)	0.22 (0.20-0.25)	0.09 (0.08-0.10)
Dehydration	0.91 (0.88-0.95)	0.29 (0.27-0.31)	0.47 (0.44-0.51)	0.12 (0.10-0.14)
Mental and behavioral disorders				
Alcohol intoxication	0.44 (0.41-0.46)	0.31 (0.29-0.33)	0.38 (0.35-0.41)	0.22 (0.20-0.24)
Diseases of the nervous system				
Transient Ischemic Attack	0.61 (0.58-0.64)	0.25 (0.23-0.27)	0.41 (0.38-0.45)	0.11 (0.10-0.13)
Diseases of the circulatory system				
Angina	0.97 (0.93-1.01)	0.31 (0.29-0.33)	0.42 (0.39-0.45)	0.23 (0.21-0.25)
Acute Myocardial Infarction	1.00 (0.96-1.04)	0.41 (0.38-0.43)	0.68 (0.64-0.72)	0.39 (0.36-0.42)
Atrial fibrillation	1.63 (1.58-1.69)	0.36 (0.34-0.38)	0.61 (0.57-0.65)	0.20 (0.18-0.22)
Heart failure	0.73 (0.69-0.76)	0.16 (0.15-0.18)	0.20 (0.18-0.23)	0.12 (0.10-0.13)
Hypertension	0.52 (0.49-0.55)	0.15 (0.14-0.16)	0.22 (0.20-0.25)	0.08 (0.06-0.09)
Stroke	1.41 (1.36-1.45)	0.49 (0.46-0.51)	0.96 (0.91-1.01)	0.29 (0.27-0.32)
Diseases of the respiratory system				
Chronic Obstructive Pulmonary Disorder	1.26 (1.22-1.31)	0.39 (0.37-0.41)	0.63 (0.59-0.67)	0.31 (0.28-0.33)
Respiratory failure	0.49 (0.46-0.52)	0.17 (0.16-0.19)	0.28 (0.26-0.31)	0.13 (0.11-0.14)
Diseases of the digestive system				
Gastroenteritis	0.52 (0.49-0.55)	0.19 (0.17-0.20)	0.32 (0.29-0.35)	0.13 (0.11-0.15)
Symptoms and abnormal findings				
Syncope	0.69 (0.65-0.72)	0.37 (0.35-0.39)	0.59 (0.55-63)	0.19 (0.17-0.21)
Factors influencing health status				
Suspected Acute Myocardial Infarction	1.64 (1.59-1.69)	0.71 (0.68-0.74)	0.99 (0.94-1.04)	0.40 (0.37-0.43)
Other	19.7 (19.6-19.9)	6.93 (6.84-7.02)	9.64 (9.48-9.80)	3.90 (3.81-4.00)

Mortality

Table 3 portrays the crude and age- and sex-standardized 30-day mortality rate for the common medical conditions. The age- and sex- standardized 30-day mortality rate was 5.1% (95% CI 5.0-5.3%) for patients admitted during weekday office hours, 5.7% (95%CI 5.5-6.0%) for patients admitted during weekday off hours, 6.4% (95%CI 6.1-6.7%) for patients admitted during weekend daytime hours, and 6.3% (95%CI 5.9-6.8%) for patients admitted during weekend nighttime hours. The medical conditions with the highest mortality in all four time periods were respiratory failure and bacteremia/sepsis. In 17 of the 20 common medical conditions examined in this study, the highest mortality was associated with an admission during weekend, of which seven medical conditions had the highest mortality associated with weekend nighttime hours admission, *i.e.* erysipelas, bacteremia/sepsis, anemia, angina, atrial fibrillation, chronic obstructive pulmonary disorder, and syncope. Urinary tract infection was the only condition associated with the highest mortality for admissions during weekday office hours (5.5% (95% CI 4.5-6.5%)). For patients admitted with hypertension or stroke, the highest mortality was associated with an admission during weekday off hours. Notably, for patients with stroke there was a substantial increase in mortality associated with admissions during weekday off hours compared with weekday office hours (13.4% versus 9.19%). For patients with anemia, there was more than a doubling in mortality for patients admitted during weekend nighttime hours compared to weekday office hours.

Table 3. Crude and age-and sex standardized 30-day mortality rates for 20 common medical conditions among acute medical patients by time of admission.

	Weekday			Weekend			
	Office hours (8.00 am-4.59 pm)	Off hours (5.00 pm-7.59 am)		Day (9.00 am-9.59 pm)		Night (10.00 pm-8.59 am) plus Friday 10.00-11.59 pm and Monday 0.00-7.59 am	
	Reference	Crude (%)	Adj. % (95%CI)	Crude (%)	Adj. % (95% CI)	Crude (%)	Adj. % (95% CI)
Overall	5.1 (5.0-5.3)	5.1	5.7 (5.5-6.0)	6.2	6.4 (6.1-6.7)	5.5	6.3 (5.9-6.8)
Common medical conditions							
Infectious diseases							
Pneumonia	9.60 (8.87-10.3)	10.3	10.1 (9.04-11.2)	11.5	10.6 (9.39-11.8)	10.1	9.92 (8.10-11.7)
Erysipelas	1.61 (0.84-2.39)	1.56	1.76 (0.58-2.94)	1.63	2.11 (0.46-3.76)	1.60	2.33 (0.00-5.46)
Bacteremia/septicemia	20.6 (18.4-22.9)	20.2	20.1 (17.4-22.9)	19.7	18.9 (15.8-21.9)	26.5	27.1 (21.6-32.6)
Urinary Tract Infection	5.45 (4.46-6.45)	4.62	4.81 (3.47-6.15)	4.59	4.41 (2.98-5.84)	3.67	4.59 (1.98-7.21)
Hematological Diseases							
Anemia	4.36 (3.55-5.18)	6.24	6.51 (4.09-8.93)	7.89	8.04 (4.76-11.3)	8.60	9.24 (3.19-15.3)
Endocrine and nutritional disease							
Diabetes	1.62 (1.00-2.25)	1.78	1.68 (0.57-2.78)	2.76	2.51 (0.87-4.15)	1.27	1.16 (0.00-2.82)
Dehydration	11.1 (9.75-12.4)	11.0	11.3 (9.31-13.3)	12.5	12.4 (9.96-14.8)	9.86	10.3 (6.12-14.4)
Mental and behavioral disorders							
Alcohol intoxication	1.92 (1.07-2.77)	1.11	1.11 (0.45-1.77)	1.98	2.24 (0.95-3.52)	NA	NA
Diseases of the nervous system							
Transient Ischemic Attack	0.51 (0.13-0.88)	0.37	0.32 (0.00-0.68)	0.99	0.83 (0.16-1.50)	NA	NA
Diseases of the circulatory system							
Angina	1.78 (1.23-2.33)	1.00	1.13 (0.44-1.82)	1.46	1.52 (0.54-2.50)	2.70	2.90 (1.26-4.54)
Acute Myocardial Infarction	6.06 (5.11-7.02)	7.06	7.20 (5.83-8.58)	7.72	8.09 (6.43-9.76)	7.06	7.05 (5.18-8.92)
Atrial fibrillation	2.05 (1.60-2.50)	2.56	2.72 (1.77-3.66)	3.04	3.20 (2.02-4.38)	3.67	3.68 (1.75-5.61)
Heart failure	8.02 (6.74-9.31)	8.41	8.59 (6.22-11.0)	13.0	12.4 (8.73-16.1)	10.1	9.20 (5.50-12.9)
Hypertension	1.19 (0.57-1.81)	1.85	1.64 (0.63-2.66)	1.52	1.22 (0.17-2.26)	NA	NA
Stroke	9.19 (8.22-10.2)	13.3	13.4 (11.7-15.0)	12.7	12.2 (10.6-13.9)	11.5	11.9 (9.17-14.7)
Diseases of the respiratory system							
Chronic Obstructive Pulmonary Disorder	4.88 (4.10-5.66)	4.87	5.08 (3.85-6.32)	6.59	6.60 (5.02-8.19)	6.06	6.80 (4.53-9.07)
Respiratory failure	23.2 (20.8-25.6)	23.4	24.0 (20.5-27.5)	28.5	28.1 (23.8-32.3)	22.8	24.9 (19.1-30.6)
Diseases of the digestive system							
Gastroenteritis	1.44 (0.77-2.12)	0.82	1.02 (0.14-1.89)	3.00	3.23 (1.57-4.90)	2.16	2.74 (0.42-5.07)
Symptoms and abnormal findings							
Syncope	0.58 (0.20-0.96)	1.00	1.09 (0.48-1.70)	0.92	0.84 (0.26-1.41)	0.89	1.22 (0.00-2.55)
Factors influencing health status							
Suspected Acute Myocardial Infarction	0.67 (0.41-0.93)	0.74	1.00 (0.54-1.47)	1.10	1.11 (0.57-1.65)	0.84	0.97 (0.17-1.77)
Other	4,33 (4.14-4.52)	4.06	4.78 (4.49-5.07)	5.04	5.45 (5.05-5.85)	4.23	5.31 (4.70-5.92)

In our analysis of the subgroup of patients admitted through the emergency room, we identified no major differences in mortality or ICU admissions by time of admission (Appendix, Table S4). The admission rates varied with the lowest admission rate during weekend nighttime hours.

DISCUSSION

Key findings

In this register-based cohort study, timing of first-time admissions varied and weekend admissions were associated with the highest mortality for the majority of the conditions examined. By including weekday off hours as a separate time of admission, we were able to discern important differences in patient characteristics, for example that the proportion of patients arriving through the emergency room changed dramatically from weekday office hours to weekday off hours.

Strengths and limitations

The key strength of this cohort study was the use of a nationwide population-based medical registry that included all first-time acute admissions to departments of medicine in Denmark. The population-based design essentially removes concerns about patient selection bias, and the CPR number assigned to all Danish residents permits unambiguous individual-level linkage among all Danish administrative and medical registries.

A concern is the accuracy of data on time of admission. While the administrative data has high accuracy in the DNRP, the accuracy of the registration of time of the day is unknown. Inaccurate registration of time of admission may introduce bias in our

estimates, but we assume such bias to be minor as the intervals range over many hours thereby limiting the misclassification between two periods. In addition, registration of time of admission is registered prospectively, independent of future events such as death or ICU admission.

Administrative databases provide extensive and valuable data, but variation in coding practices is an inherent limitation of administrative databases.[24] Often an acute condition associate with a chronic condition and the extent of diagnostic work-up or complications during admission may influence coding practices.[21] The accuracy of some diagnoses in the DNRP is known, for example the diagnosis of chronic obstructive pulmonary disorder, the non-specific diagnosis of syncope, and the diagnosis of acute stroke, and all have been found to have reasonable high accuracy. [25-27] The accuracy of diagnostic coding for the conditions in the CCI has also been shown to be high.[28] An ICU admission was identified with a special procedure code for intensive care and this variable has been shown to have high accuracy.[29] Since we used a population-based registry to identify large groups of patients diagnosed with the same ICD-10 codes, we assume that misclassification bias had only a minor impact on our results, if any.

Interpretation

The findings from our study indicate that the overall reasons for admissions changed from office hours to off hours and weekend hours. For the majority of the medical conditions examined, weekend admission associated with a higher mortality compared to admission during weekday office hours. In the case of anemia, which demonstrated

a tremendous decrease in admission rates after weekday office hours, the mortality rate and risk of an ICU admission more than doubled when patients were admitted during the weekend, which may infer that it was the most severely ill patients who were admitted during weekends. Previous studies of stroke, a common disorder in acute medical patients, found that the weekend effect disappeared after adjustment for deferred admission and disease severity.[30-32] No previous studies presenting admission rates or changes in reasons for admission associated with time of admission were identified.

Although the Danish health care system differs from those in other countries, our study lends support to previous evidence of a higher mortality associated with an acute admission during the weekend but extends this by examining office hours versus off hours, weekend daytime hours and weekend nighttime hours. [1-16] The limited availability of the patients' personal GP and specialized care at the hospitals are assumed to apply to both weekday off hours and to weekend hours. Moreover, it is known that the referral rates of acute hospital admission from the GPs increase outside office hours.[33] Classifying time of admission into four periods, including day and night hours of the weekend, was an attempt to provide a more subtle description of the weekend effect. All earlier studies examined this effect by defining the weekend as starting on Friday at midnight and ending on Sunday at midnight. A few studies have examined mortality associated with admissions during off hours,[8,9] but no studies of an overall cohort of acute patients have distinguished between weekday off hours and weekend daytime and nighttime hours.

A high proportion of patients arrived through the emergency room outside office hours. The reasons could be associated with availability of GPs for consultation, or it could be patient-related, associated with proportionally more patients with severe diseases presenting to departments of medicine outside office hours. The latter explanation is supported by the higher proportion of ICU admissions during weekday off hours and the weekend, and ICU admission may be an indicator of severity. In contrast to our findings, a previous US study based on medical record review of 824 admissions to general medicine units found that weekend admissions were associated with a lower risk of an ICU transfer.[9] However, differences in ICU settings between the US and Europe must be taken into account when making international comparisons of ICU admission rates.[34]

The present study may add important knowledge to healthcare planners about patient characteristics associated with admission outside office hours and the associated risk of ICU admission and death.

In conclusion, timing of first-time admissions varied and weekend admissions were associated with the highest mortality for the majority of the conditions examined. By including weekday off hours as a separate time of admission, we were able to discern important differences in patient characteristics.

Contributor statement:

BV-H, AHR, HTS, and CFC contributed to the study conception, design, and the interpretation of data. BV-H, AHR, HTS, and CFC were responsible for the acquisition of data. BV-H analyzed and drafted the manuscript. All authors critically revised the manuscript and approved the final version.

Competing interests:

The authors report no competing interest in conducting this study.

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Data sharing:

No additional unpublished data are available from the present study.

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Table S1. ICD-10 diagnoses of common conditions among acute medical patients

Pneumonia	J12-J18, A48.1, A70.9
Erysipelas	A46
Bacteremia/septicemia	A40-41, A02.1, A20.7, A21.7, A22.7, A22.9B, A26.7, A28.2B, A32.7, A39.2-4, A42.7, A49.9A, A54.8G, B37.7, B49.9A, J95.0A
UTI	N30, N34, N39.0
Anemia	D50-64
Diabetes	E10-14
Dehydration	E86
Alcohol Intoxication	F10
Transient ischemic attack	G45
Angina	I20, I24, I25
AMI	I21
AFLI	I48
Heart Failure	I50, I11.0, I13.0, I13.2
Hypertension	I10, D15
Stroke	I60-61, I63-64
COPD	J40-44, J47
Respiratory failure	J96
Gastroenteritis	A0
Syncope	R55
Suspected AMI	Z03.4

Table S2. ICD-10 codes for the Charlson Comorbidity Index conditions

Charlson score of 1:	
Myocardial infarction	I21, I22, I23
Congestive heart failure	I50, I11.0, I13.0, I13.2
Peripheral vascular disease	I70, I71, I72, I73, I74, I77
Cerebrovascular disease	I60-I69, G45, G46
Dementia	F00-F03, F05.1, G30
Chronic pulmonary disease	J40-J47, J60-J67, J68.4, J70.1, J70.3, J84.1, J92.0, J96.1, J98.2, J98.3
Connective tissue disease	M05, M06, M08, M09, M30, M31, M32, M33, M34, M35, M36, D86
Ulcer disease	K22.1, K25-K28
Mild liver disease	B18, K70.0-K70.3, K70.9, K71, K73, K74, K76.0
Diabetes mellitus	E10.0-E10.2, E10.9, E11.0-E11.1, E11.9
Charlson score of 2:	
Hemiplegia	G81, G82
Diabetes with end organ damage	E10.2-E10.8, E11.2-E11.8
Any tumor	C00-C75
Leukemia	C91-C95
Lymphoma	C81-C85, C88, C90, C96
Charlson score of 3:	
Moderate to severe liver disease	B15.0, B16.0, B16.2, B19.0, K70.4, K72, K76.6, I85
Charlson score of 6:	
Metastatic solid tumor	C76-C80
AIDS	B21-B24

Table S3. ICU admissions within three days after admission in medical conditions among acute medical patients according to time of admission

	Weekday				Weekend			
	Office hours (8.00 am-4.59 pm)		Off hours (5.00 pm-7.59 am)		Weekend daytime hours (9.00 am-9.59 pm)		Weekend nighttime hours (10.00 pm-8.59 am) plus Friday 10.00-11.59 pm and Monday 0.00-7.59 am	
	n	ICU admissions (% of group)	n	ICU admissions (% of group)	n	ICU admissions (% of group)	n	ICU admissions (% of group)
Infectious diseases								
Pneumonia	5,886	165 (2.8)	2,797	118 (4.2)	2,197	75 (3.4)	978	55 (5.6)
Erysipelas	991	2 (0.2)	513	2 (0.4)	367	1 (0.3)	125	1 (0.8)
Bacteremia/septicemia	1,201	132 (11.0)	759	84 (11.1)	563	68 (12.1)	238	29 (12.2)
Urinary Tract Infection	1,944	6 (0.3)	996	6 (0.6)	740	2 (0.3)	300	1 (0.3)
Hematological diseases								
Anemia	2,384	15 (0.6)	417	7 (1.7)	266	7 (2.6)	93	4 (4.3)
Endocrine and nutritional diseases								
Diabetes	1,540	52 (3.4)	507	31 (6.1)	326	28 (8.6)	158	18 (11.4)
Dehydration	2,073	8 (0.4)	953	7 (0.7)	697	4 (0.6)	213	0
Mental and behavioral disorders								
Alcohol intoxication	989	17 (1.7)	994	18 (1.8)	556	11 (2.0)	388	16 (4.1)
Diseases of the nervous system								
Transient ischemic attack	1,380	0	811	2 (0.3)	609	1 (0.2)	200	1 (0.5)
Diseases of the circulatory system								
Angina	2,191	25 (1.1)	1,000	14 (1.4)	616	11 (1.8)	408	7 (1.7)
Acute Myocardial Infarction	2,274	85 (3.7)	1,317	65 (4.9)	997	43 (4.3)	694	35 (5.0)
Atrial Fibrillation	3,707	23 (0.6)	1,170	8 (0.7)	889	8 (0.9)	354	2 (0.6)
Heart failure	1,645	27 (1.6)	535	29 (5.4)	300	13 (4.3)	207	12 (5.8)
Hypertension	1,173	3 (0.3)	487	3 (0.6)	329	1 (0.3)	136	1 (0.7)
Stroke	3,187	84 (2.6)	1,587	90 (5.7)	1,407	46 (3.3)	515	30 (5.8)
Diseases of the respiratory system								
Chronic Obstructive Pulmonary Disorder	2,869	91 (3.2)	1,273	65 (5.1)	926	44 (4.8)	545	37 (6.8)
Respiratory failure	1,120	152 (13.6)	559	74 (13.2)	414	81 (19.6)	224	38 (17.0)
Diseases of the digestive system								
Gastroenteritis	1,179	3 (0.3)	612	7 (1.1)	466	6 (1.3)	231	1 (0.4)
Symptoms and abnormal findings								
Syncope	1,554	4 (0.3)	1,195	8 (0.7)	865	3 (0.4)	336	3 (0.9)
Factors influencing health status								
Suspected Acute Myocardial Infarction	3,719	6 (0.2)	2,304	4 (0.2)	1,455	8 (0.6)	712	7 (1.0)
Other	44,758	860 (1.9)	22,5626	691 (3.1)	14,155	462 (3.3)	6,921	323 (4.7)
Total (within three days)	87,764	1,760 (2.0)	43,312	1,333 (3.1)	29,140	923 (3.2)	13,976	521 (4.4)
Total (complete length of hospital stay)		2,603 (3.0)		1,712 (4.0)		1,190 (4.1)		746 (5.3)

Table S4. Admission rates, age-and-sex standardized 30-day mortality and ICU admission within three days after the index date for the patients admitted through the emergency room

	Weekday		Weekend	
	Office hours (8.00 am-4.59 pm)	Off hours (5.00 pm-7.59 am)	Weekend daytime hours (9.00 am-9.59 pm)	Weekend nighttime hours (10.00 pm-8.59 am) plus Friday 10.00-11.59 pm and Monday 0.00-7.59 am
Total (n)	13,225	14,492	8,810	4,618
Hourly admission rate	5.83 (5.73-5.93)	4.46 (4.39-4.53)	6.00 (5.87-6.12)	2.60 (2.53-2.68)
Crude Mortality Age- and sex-standardized mortality	5.87 (5.47-6.26)	4.80 5.51 (5.11-5.90)	5.86 6.19 (5.68-6.69)	4.79 5.95 (5.20-6.70)
ICU n (%)	622 (4.70)	657 (4.53)	448 (5.09)	266 (5.76)

STROBE Statement—Checklist of items that should be included in reports of ***cohort studies***

	Item No	Recommendation	Page
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	2
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	2
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	4
Objectives	3	State specific objectives, including any prespecified hypotheses	5
Methods			
Study design	4	Present key elements of study design early in the paper	5
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	5
Participants	6	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up	6
		(*b*) For matched studies, give matching criteria and number of exposed and unexposed	
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	6-7
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	*6-7*
Bias	9	Describe any efforts to address potential sources of bias	7-8
Study size	10	Explain how the study size was arrived at	6
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	8
		(*b*) Describe any methods used to examine subgroups and interactions	9
		(*c*) Explain how missing data were addressed	
		(*d*) If applicable, explain how loss to follow-up was addressed	
		(*e*) Describe any sensitivity analyses	
Results			
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	9
		(b) Give reasons for non-participation at each stage	
		(c) Consider use of a flow diagram	
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	9-10
		(b) Indicate number of participants with missing data for each variable of interest	
		(c) Summarise follow-up time (eg, average and total amount)	
Outcome data	15*	Report numbers of outcome events or summary measures over time	13-17
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which	16

		confounders were adjusted for and why they were included	
		(*b*) Report category boundaries when continuous variables were categorized	
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	17
Discussion			
Key results	18	Summarise key results with reference to study objectives	17
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	17-18
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	18-19
Generalisability	21	Discuss the generalisability (external validity) of the study results	19
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	21

*Give information separately for exposed and unexposed groups.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at http://www.strobe-statement.org.

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Out of Hours and Weekend Admissions to Danish Medical Departments: Admission Rates and 30-Day Mortality for 20 Common Medical Conditions

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ORIGINAL RESEARCH

Out of Hours and Weekend Admissions to Danish Medical Departments: Admission Rates and 30-Day Mortality for 20 Common Medical Conditions

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Abstract

Objectives: Knowledge on the combined weekly and diurnal variation in timing of admissions and mortality for acute medical patients is limited. The aim of the study was to examine hospital admission rates and mortality rates for patients with common medical conditions according to time of admission.

Design: Nationwide population-based cohort study.

Setting: Population of Denmark.

Participants: Using the Danish National Registry of Patients (DNRP) covering all Danish hospitals, we identified all adults with the first acute admission to a medical department in Denmark during 2010. Readmissions and transfers were excluded.

Primary and secondary outcome measures: Hourly admission rates and age- and sex-standardized 30-day mortality rates comparing weekday office hours, weekday out of hours, weekend daytime hours, and weekend nighttime hours.

Results: In total, 174,192 acute medical patients were included in the study. The admission rates (patients per hour) were 38.7 (95% CI 38.4-38.9) during weekday office hours, 13.3 (95% CI 13.2-13.5) during weekday out of hours, 19.8 (95% CI 19.6-20.1) during weekend daytime hours, and 7.9 (95% CI 7.8-8.0) during weekend nighttime hours. Admission rates varied between medical conditions. The proportion admitted through the emergency department and to an intensive care unit (ICU) increased outside office hours. The age- and sex-standardized 30-day mortality rate was 5.1% (95% CI 5.0-5.3%) after admission during weekday office hours, 5.7% (95% CI 5.5-6.0%)

after admission during weekday out of hours, 6.4% (95% CI 6.1-6.7%) after admission during weekend daytime hours, and 6.3% (95% CI 5.9-6.8%) after admission during weekend nighttime hours. For the majority of the medical conditions examined, weekend admission was associated with highest mortality.

Conclusions: While admission rates decreased from office hours to weekend hours there was an observed increase in mortality. This may reflect differences in severity of illness as the proportion admitted to an ICU increased during the weekend.

ARTICLE SUMMARY

Strengths and limitations of this study

- This study is the first to analyze hourly admission rates and mortality rates associated with time of admission in 20 common conditions among acute medical patients in a population-based design
- We provide a subtle categorization of time of admission including both weekday office hours, weekday out of hours, weekend daytime hours and weekend nighttime hours
- Our study lacked clinical data on severity of disease and staffing level, but included information on the proportion admitted to intensive care units and the proportion receiving specific intensive care treatment according to time of admission.

INTRODUCTION

Acute hospital admission rate decreases during weekend, but an admission during weekend has been associated with higher in-hospital mortality, an association termed "the weekend effect".[1-16] The weekend effect has been observed among acutely hospitalized patients in differing healthcare systems, including Canada, the US, and Australia, as well as in European countries. Understanding the higher short-term mortality associated with weekend admissions is important both for clinicians and healthcare planners. Two possible explanations for the weekend effect are the changes in the availability of specialized care or changes in patient characteristics, *e.g.* disease severity.[17]

A more subtle categorization of time of admission in patients admitted during weekday office hours and out of hours, as well as daytime hours and nighttime hours during the weekend may clarify important differences in patient characteristics. Furthermore, admission rates for common medical conditions in these time periods may serve as a proxy of the changes in referral threshold and together with mortality rates add to the understanding of the weekend effect. Variation in timing of admission and mortality rates for common medical conditions has to our best knowledge not previously been examined. Previous studies examining "out of hours" and mortality have primarily investigated "out of hours" as the time outside regular hours/office hours, not distinguishing between "Office" and "Out of hours" hours during weekdays, as well as between daytime and nighttime hours of the weekend.[8-9]

We therefore examined the hourly admission rates and 30-day mortality rates for patients with 20 common medical conditions comparing weekday office hours, weekday out of hours, weekend daytime hours, and weekend nighttime hours in a cohort of acute medical patients with their first admission to departments of medicine during 2010 in Denmark.

METHODS

Study design and setting

In this register-based historic cohort study using prospectively collected data, we identified all acute hospital admissions to medical departments in Denmark between 1 January and 31 December 2010, as recorded in the Danish National Registry of Patients (DNRP). The DNRP is a central medical registry covering both public and private hospitals that record information on all hospital admissions to non-psychiatric hospitals since 1977 and all visits to emergency departments and hospital specialist clinics since 1995. The record of each admission or visit is linked to the unique CPR number. In the study period, the DNRP was managed by the National Board of Health, but is currently managed by Statens Serum Institut (SSI). After necessary approvals, data from the DNRP can be accessed by researchers in Denmark by application to SSI. In Denmark, the private hospitals account for less than 1% of the total number of beds and they do not provide acute care.[18]

General practitioners (GPs) have a key role in referring patients to the hospital departments since virtually all Danish residents are affiliated with a personal GP.

Outside regular office hours, GPs serve the patients from central regional clinics providing both phone service and consultation. Acute hospital admission is also available through a 1-1-2 emergency call, which provides ambulance service to the patient.[19] Finally, patients can present themselves to an emergency department on a 24-hour basis.[20] In the study period some emergency departments implemented a mandatory preadmission assessment based on a telephone call before arrival.

Denmark has a free, tax-funded health care system, which assures that all residents (5,534,738 million persons as of 1 January 2010) in both rural and urban areas have unrestricted and equal access to GPs and to specialist care in hospitals.[21,22]

Study population

The cohort, which included all patients with their first acute admission to medical departments in Denmark between 1 January and 31 December 2010, has previously been described.[23] For this present study, we excluded patients with an inpatient stay in a hospital department within the preceding 30 days or earlier on the day of admission.

Time of admission

Time of admission was defined as weekday office hours, weekday out of hours, weekend daytime hours, and weekend nighttime hours. Public holidays, *e.g.*, Easter and Christmas, were considered weekend days. Weekday office hours were from Monday to Friday from 8:00 am to 4:59 pm. Weekday out of hours were from Monday to Friday from 5:00 pm to 7:59 am, except Friday night from 10:00 pm-11:59 pm and Monday morning from 12:00 am to 7.59 am, which were considered part of the

weekend. Weekend daytime hours were Saturday and Sunday from 9:00 am to 9:59 pm. Weekend nighttime hours were Saturday and Sunday from 10:00 pm to 11:59 pm and from 12:00 am to 8:59 am plus Friday night from 10:00 pm to 11:59 pm, and Monday from 12:00 am to 7:59 am. Admission rates were computed hourly according to time of admission. An overall estimate of the admission rate per 100,000 citizen (>=15 years) was computed.

Mortality

Each Danish resident is assigned a unique personal identification number (CPR number) at birth or upon immigration by the Danish Civil Registration System (CRS).[24] Information on all-cause mortality within 30 days following the index date was captured by linking patients' CPR number to the CRS. The CRS was established in 1968 to collect and maintain information on vital status, marital status, residency, and migration for all residents of Denmark. The CRS thus contains complete up-to-date data on the vital status of all patients in our study. Patients were followed from their index date until death from any cause, emigration, or 30 days after the index date, whichever came first.

Patient characteristics

The DNRP provided the unique code for each hospital and department, admission type (*i.e*. acute), date of admission (*index date*), hour and minute of admission (00.00-23.59 hours), source of admission (hospital specialist clinic, emergency department, or direct referral), procedure codes for an intensive care unit (ICU) admission and specific intensive care treatment, date of discharge, and discharge diagnoses, with one primary

diagnosis reflecting the reason for admission and up to 19 secondary diagnoses, indicating additional chronic or acute diseases. Diagnoses were coded according to *the International Classification of Diseases*, version 10 (ICD-10).

By tabulation of the primary ICD-10 diagnoses assigned after the index admission, considered to be the main reason for admission, we identified 20 common conditions among acute medical patients, *i.e*. pneumonia, erysipelas, bacteremia/sepsis, urinary tract infection, anemia, diabetes, dehydration, alcohol intoxication, transient ischemic attack, angina, acute myocardial infarction, atrial fibrillation, heart failure, hypertension, stroke, chronic obstructive pulmonary disorder, respiratory failure, gastroenteritis, syncope, and suspected acute myocardial infarction (ICD-10 codes provided in Appendix, Table S1).

To capture clinically important morbidity, data on the 19 conditions included in the Charlson Comorbidity Index (CCI) were obtained from the DNRP for the five years preceding the index date (ICD-10 codes provided in Appendix, Table S2). The CCI score was divided in low (score of 0), moderate (score of 1-2), and high (score of 3 or higher). From CRS, data on marital status (married, never married, divorced, widowed, and unknown) were provided. We computed length of hospital stay as time from the index date to final hospital discharge, including in-hospital and inter-hospital transfers.

Statistical analysis

We classified patients as admitted during weekday office hours, weekday out of hours, weekend daytime hours, and weekend nighttime hours, and characterized them according to patient characteristics. The hourly admission rates and the 30-day

mortality rates were computed for the common medical conditions according to time of admission. To compute comparable 30-day mortality rates for different times of admission, we used direct standardization.[25] We applied the observed age- and sex-specific mortality rates to a standard population defined as the patients admitted during weekday office hours. That is, for each time period, we estimated what would have been the 30-day mortality rate in our standard population if the age- and sex-specific mortality rates equaled those of the time period of interest. In a sensitivity analysis, we included the CCI score in the standardization. We also reported the proportions of patients admitted to an ICU within three days following the index date and during the whole hospital stay. Additionally, we reported the proportions receiving specific intensive care treatment. An ICU admission serves as a proxy for the severity of the disease and of the availability of an ICU bed.

In a subgroup analysis, the admission rate, 30-day mortality rate, and ICU admissions during the four time periods were analyzed only among patients admitted through the emergency department. To acknowledge the effect from public holidays on our estimates, we analyzed the mortality rates associated with public holidays compared to all other days, including weekdays and weekend. We used direct standardization to the age and gender distribution of the study population admitted outside public holidays. Data were analyzed with the statistical software package STATA (version 11, Stata Corp., College Station, Texas, USA). The study was approved by the Danish Data Protection Agency (record number 1-16-02-1-08). Because the study was based solely on data from administrative and medical databases, no further approval from the Ethics Committee was required.

RESULTS

Patient characteristics

A total of 264,265 patients with an acute first-time admission to medical departments in Denmark during 2010 were registered. After excluding patients without residency in Denmark (n=505) and patients with a hospital admission within the preceding 30 days or on the day of the index admission (n=89,568), 174,192 patients were included in the study. Of these patients, 50.4% (n=87,764) were admitted during weekday office hours, 24.9% (n=43,312) during weekday out of hours, 16.7% (n=29,140) during weekend daytime hours, and 8.0% (n=13,976) during weekend nighttime hours. As shown in Table 1a, patients admitted during weekday office hours tended to be older and had slightly higher CCI scores than patients admitted during other time periods. Weekend nighttime hours were the only time of admission when males constituted the highest proportion of patients (50.8%). No major differences among patients were observed with regard to the individual CCI conditions. During weekday office hours, 15.1% were admitted through the emergency department, while 33.5% were admitted through the emergency department during weekday out of hours. Similarly, weekend daytime and weekend nighttime hours were associated with a high rate of admissions through the emergency department (30.2% and 33.0%, respectively).

Table 1a. Demographic and clinical characteristics of 174,192 patients with an acute admission to a department of medicine, by time of admission, Denmark, 2010.

	Weekday		Weekend	
	Office hours (8.00 am-4.59 pm)	Out of hours (5.00 pm-7.59 am)	Day (9.00 am -9.59 pm)	Night (10.00 pm-8.59 am) plus Friday 10.00-11.59 pm and Monday 12.00 am - 7.59 am
Overall	87,764 (50.4%)	43,312 (24.9%)	29,140 (16.7%)	13,976 (8.0%)
Age groups				
15-39	9,291 (10.6)	7,246 (16.7)	3,960 (13.6)	2,528 (18.1)
40-59	19,888 (22.7)	10,902 (25.2)	6,764 (23.2)	3,456 (24.7)
60-79	36,722 (41.8)	15,794 (36.5)	11,079 (38.0)	5,146 (36.8)
80+	21,863 (24.9)	9,370 (21.6)	7,337 (25.2)	2,846 (20.4)
Age, Median (years (IQR))	68 (54-79)	64 (47-78)	67 (51-80)	64 (46-77)
Gender				
Female	45,877 (52.3)	22,175 (51.2)	15,073 (51.7)	6,880 (49.2)
Male	41,887 (47.7)	21,1375 (48.8)	14,067 (48.3)	7,096 (50.8)
Charlson Comorbidity Index score				
0	49,384 (56.3)	25,710 (59.4)	16,647 (57.1)	8,055 (57.6)
1-2	27,302 (31.1)	12,687 (29.3)	8,996 (30.9)	4,267 (30.5)
3+	11,078 (12.6)	4,915 (11.4)	3,497 (12.0)	1,654 (11.8)
Presence of diseases included in the Charlson Comorbidity Index				
Myocardial infarction	3,246 (3.7)	1,658 (3.8)	1,117 (3.8)	590 (4.2)
Congestive heart failure	5,735 (6.5)	2,477 (5.7)	1,748 (6.0)	913 (6.5)
Peripheral vascular disease	4,683 (5.3)	1,926 (4.4)	1,388 (4.8)	686 (4.9)
Cerebrovascular disease	8,110 (9.2)	4,052 (9.3)	2,917 (10.0)	1,353 (9.8)
Dementia	1,920 (2.2)	1,013 (2.3)	769 (2.6)	296 (2.1)
Chronic pulmonary disease	9,934 (11.3)	4,758 (11.0)	3,296 (11.3)	1,691 (12.1)
Connective tissue disease	2,977 (3.4)	1,181 (2.7)	889 (3.1)	386 (2.8)
Ulcer disease	2,479 (2.8)	1,138 (2.6)	778 (2.7)	367 (2.6)
Mild liver disease	1,435 (1.6)	691 (1.6)	451 (1.6)	209 (1.5)
Diabetes without end-organ damage	7,154 (8.2)	3,362 (7.8)	2,268 (7.8)	1,099 (7.9)
Diabetes with end-organ damage	4,337 (4.9)	2,101 (4.9)	1,386 (4.8)	675 (4.8)
Hemiplegia	313 (0.4)	163 (0.4)	106 (0.4)	53 (0.4)
Moderate to severe renal disease	3,036 (3.5)	1,289 (3.0)	918 (3.2)	432 (3.1)
Non-metastatic solid tumor	7,555 (8.6)	3,157 (7.3)	2,393 (8.2)	1,032 (7.4)
Leukaemia	500 (0.6)	193 (0.5)	131 (0.5)	56 (0.4)
Lymphoma	874 (1.0)	354 (0.8)	270 (0.9)	107 (0.8)
Moderate to severe liver disease	511 (0.6)	202 (0.5)	159 (0.6)	85 (0.6)
Metastatic cancer	1,035 (1.2)	373 (0.9)	360 (1.2)	140 (1.0)
AIDS	152 (0.2)	85 (0.2)	50 (0.2)	23 (0.2)
Marital status				
Married	40,881 (46.6)	18,719 (43.2)	12,794 (43.9)	6,358 (45.5)
Never married	14,140 (16.1)	9,206 (21.3)	5,364 (18.4)	2,981 (21.3)
Divorced	12,414 (14.1)	6,486 (15.0)	4,230 (14.5)	2,064 (14.8)
Widowed	20,325 (23.2)	8,904 (20.6)	6,751 (23.2)	2,573 (18.4)
Unknown	4	0	1	0
Admission source				
Hospital outpatient specialist clinic	5,781 (6.6)	2,251 (5.2)	1,139 (3.9)	541 (3.9)
Emergency department	13,225 (15.1)	14,492 (33.5)	8,810 (30.2)	4,618 (33.0)
Other	69,438 (79.0)	27,343 (63.1)	19,610 (67.3)	8,997 (64.4)
Length of hospital stay [Median (days)]	3 (1-7)	2 (1-7)	3 (1-7)	3 (1-6)
Common medical conditions				
Pneumonia	5,886 (6.7)	2,797 (6.5)	2,197 (7.5)	978 (7.0)
Erysipelas	991 (1.1)	513 (1.2)	367 (1.3)	125 (0.9)
Bacteremia/Sepsis	1,201 (1.4)	759 (1.8)	563 (1.9)	238 (1.7)
Urinary tract infection	1,944 (2.2)	996 (2.3)	740 (2.5)	300 (2.2)
Anemia	2,384 (2.7)	417 (1.0)	266 (0.9)	93 (0.7)
Diabetes	1,540 (1.8)	507 (1.2)	326 (1.1)	158 (1.1)
Dehydration	2,073 (2.4)	953 (2.2)	697 (2.4)	213 (1.5)
Alcohol intoxication	989 (1.1)	994 (2.3)	556 (1.9)	388 (2.8)
Transient ischemic attack	1,380 (1.6)	811 (1.9)	609 (2.1)	200 (1.4)
Angina	2,191 (2.5)	1,000 (2.3)	616 (2.1)	408 (2.9)

Acute myocardial infarction	2,274 (2.6)	1,317 (3.0)	997 (3.4)	694 (5.0)
Atrial fibrillation	3,707 (4.2)	1,170 (2.7)	889 (3.1)	354 (2.5)
Heart failure	1,645 (1.9)	535 (1.2)	300 (1.0)	207 (1.5)
Hypertension	1,173 (1.3)	487 (1.1)	329 (1.1)	136 (1.0)
Stroke	3,187 (3.6)	1,587 (3.7)	1,407 (4.8)	515 (3.7)
Chronic obstructive pulmonary disorder	2,869 (3.3)	1,273 (2.9)	926 (3.2)	545 (3.9)
Respiratory failure	1,120 (1.3)	559 (1.3)	414 (1.4)	224 (1.6)
Gastroenteritis	1,179 (1.3)	612 (1.4)	466 (1.6)	231 (1.7)
Syncope	1,554 (1.8)	1,195 (2.8)	865 (3.0)	336 (2.4)
Suspected acute myocardial infarction	3,719 (4.2)	2,304 (5.3)	1,455 (5.0)	712 (5.1)
Other	44,758 (51.0)	22,526 (52.0)	14,155 (44.6)	6,921 (49.5)

Abbreviation: IQR= interquartile range

Table 1b. ICU admissions and ICU procedures

	Weekday		Weekend	
	Office hours (8.00 am-4.59 pm)	Out of hours (5.00 pm-7.59 am)	Day (9.00 am -9.59 pm)	Night (10.00 pm-8.59 am) plus Friday 10.00-11.59 pm and Monday 12.00 am - 7.59 am
	n (%)	n (%)	n (%)	n (%)
Total	87,764 (100)	43,312 (100)	29,140 (100)	13,976 (100)
ICU admissions	2603 (3.0)	1,712 (4.0)	1,190 (4.1)	746 (5.3)
ICU procedures				
Mechanical ventilation	1268 (1.4)	795 (1.8)	551 (1.9)	321 (2.3)
Non-invasive mechanical ventilation	634 (0.7)	369 (0.9)	259 (0.9)	159 (1.1)
Inotropes/vasopressor	1,024 (1.2)	624 (1.4)	443 (1.5)	260 (1.9)
Renal replacement therapy	229 (0.3)	136 (0.3)	94 (0.3)	53 (0.4)
Intensive care but no procedures	813 (0.9)	597 (1.4)	414 (1.4)	279 (2.0)

Abbreviations: ICU=Intensive Care Unit

Weekend nighttime hours were associated with the highest proportion of patients admitted to an ICU within the first three days (4.4%) compared to weekend daytime hours (3.2%), weekday out of hours (3.1%), and weekday office hours (2.0%) (Appendix, Table S3). For more than half of the individual medical conditions we examined, the highest risk of an ICU admission within three days after the index date was associated with an admission during weekend nighttime hours (Appendix, Table S3). For all 20 medical conditions except respiratory failure, admission weekday office hours were associated with the lowest risk of an ICU admission. In addition, we found that the proportion of patients receiving specific intensive care treatments, including mechanical ventilation, renal replacement therapy, and use of inotropes/vasopressors, was highest for the patients who were admitted during weekend nighttime hours. The proportion of the patients, who received multiple therapies was highest among the patients admitted outside office hours (Table 1b).

Admission rates

The admission rate during weekday office hours was 38.7 (95% Confidence Intervals (CI) 38.4-38.9) patients per hour, and corresponding figures were 13.3 (95% CI 13.2-13.5) during weekday out of hours, 19.8 (95% CI 19.6-20.1) during weekend daytime hours, and 7.9 (95% CI 7.8-8.0) during weekend nighttime hours (Table 2). The hourly admission rates per 100,000 citizen (>=15 years) in the four time periods were 0.91 (95% CI 0.87-0.95), 0.31 (95% CI 0.29-0.33), 0.47 (95% CI 0.43-0.50) and 0.19 (95% CI 0.17-0.21), respectively. Among the common medical conditions, pneumonia had the overall highest admission rate in all time periods. Anemia, diabetes, atrial fibrillation,

and heart failure had the relatively largest decreases in admission rates from weekday office hours to the other time periods while a condition like alcohol intoxication was associated with a more stable admission rate across time periods. The medical conditions with the lowest admission rates during weekend nighttime hours were anemia, erysipelas, diabetes, and hypertension.

Table 2. Hourly admission rates for 20 common medical conditions by time of admission.

	Weekday		Weekend	
	Office hours (8.00 am-4.59 pm)	Out of hours (5.00 pm-7.59 am)	Day (9.00 am-9.59 pm)	Night (10.00 pm-8.59 am) plus Friday 10.00-11.59 pm and Monday 12.00 am - 7.59 am
Overall	38.7 (38.4-38.9)	13.3 (13.2-13.5)	19.8 (19.6-20.1)	7.9 (7.8-8.0)
Common medical conditions				
Infectious diseases				
Pneumonia	2.60 (2.53-2.66)	0.86 (0.83-0.89)	1.50 (1.43-1.56)	0.55 (0.52-0.59)
Erysipelas	0.44 (0.41-0.47)	0.16 (0.14-0.17)	0.25 (0.22-0.28)	0.07 (0.06-0.08)
Bacteremia/septicemia	0.53 (0.50-0.56)	0.23 (0.22-0.25)	0.38 (0.35-0.42)	0.13 (0.12-0.15)
Urinary Tract Infection	0.86 (0.82-0.90)	0.31 (0.29-0.33)	0.50 (0.47-0.54)	0.17 (0.15-0.19)
Hematological Diseases				
Anemia	1.05 (1.01-1.09)	0.13 (0.12-0.14)	0.18 (0.16-0.20)	0.05 (0.04-0.06)
Endocrine and nutritional disease				
Diabetes	0.68 (0.65-0.71)	0.16 (0.14-0.17)	0.22 (0.20-0.25)	0.09 (0.08-0.10)
Dehydration	0.91 (0.88-0.95)	0.29 (0.27-0.31)	0.47 (0.44-0.51)	0.12 (0.10-0.14)
Mental and behavioral disorders				
Alcohol intoxication	0.44 (0.41-0.46)	0.31 (0.29-0.33)	0.38 (0.35-0.41)	0.22 (0.20-0.24)
Diseases of the nervous system				
Transient Ischemic Attack	0.61 (0.58-0.64)	0.25 (0.23-0.27)	0.41 (0.38-0.45)	0.11 (0.10-0.13)
Diseases of the circulatory system				
Angina	0.97 (0.93-1.01)	0.31 (0.29-0.33)	0.42 (0.39-0.45)	0.23 (0.21-0.25)
Acute Myocardial Infarction	1.00 (0.96-1.04)	0.41 (0.38-0.43)	0.68 (0.64-0.72)	0.39 (0.36-0.42)
Atrial fibrillation	1.63 (1.58-1.69)	0.36 (0.34-0.38)	0.61 (0.57-0.65)	0.20 (0.18-0.22)
Heart failure	0.73 (0.69-0.76)	0.16 (0.15-0.18)	0.20 (0.18-0.23)	0.12 (0.10-0.13)
Hypertension	0.52 (0.49-0.55)	0.15 (0.14-0.16)	0.22 (0.20-0.25)	0.08 (0.06-0.09)
Stroke	1.41 (1.36-1.45)	0.49 (0.46-0.51)	0.96 (0.91-1.01)	0.29 (0.27-0.32)
Diseases of the respiratory system				
Chronic Obstructive Pulmonary Disorder	1.26 (1.22-1.31)	0.39 (0.37-0.41)	0.63 (0.59-0.67)	0.31 (0.28-0.33)
Respiratory failure	0.49 (0.46-0.52)	0.17 (0.16-0.19)	0.28 (0.26-0.31)	0.13 (0.11-0.14)
Diseases of the digestive system				
Gastroenteritis	0.52 (0.49-0.55)	0.19 (0.17-0.20)	0.32 (0.29-0.35)	0.13 (0.11-0.15)
Symptoms and abnormal findings				
Syncope	0.69 (0.65-0.72)	0.37 (0.35-0.39)	0.59 (0.55-63)	0.19 (0.17-0.21)
Factors influencing health status				
Suspected Acute Myocardial Infarction	1.64 (1.59-1.69)	0.71 (0.68-0.74)	0.99 (0.94-1.04)	0.40 (0.37-0.43)
Other	19.7 (19.6-19.9)	6.93 (6.84-7.02)	9.64 (9.48-9.80)	3.90 (3.81-4.00)

1

2

3

Mortality

Table 3 portrays the crude and age- and sex-standardized 30-day mortality rate for the common medical conditions. The age- and sex- standardized 30-day mortality rate was 5.1% (95% CI 5.0-5.3%) for patients admitted during weekday office hours, 5.7% (95%CI 5.5-6.0%) for patients admitted during weekday out of hours, 6.4% (95%CI 6.1-6.7%) for patients admitted during weekend daytime hours, and 6.3% (95%CI 5.9-6.8%) for patients admitted during weekend nighttime hours. The medical conditions with the highest mortality rate in all four time periods were respiratory failure and bacteremia/sepsis. In 17 of the 20 common medical conditions examined in this study, the highest mortality rate was associated with an admission during weekend, of which seven medical conditions had the highest mortality rate associated with weekend nighttime hours admission, *i.e.* erysipelas, bacteremia/sepsis, anemia, angina, atrial fibrillation, chronic obstructive pulmonary disorder, and syncope. Urinary tract infection was the only condition associated with the highest mortality rate for admissions during weekday office hours (Table 3) For patients admitted with hypertension or stroke, the highest mortality rate was associated with an admission during weekday out of hours. Notably, for patients with stroke there was a substantial increase in mortality rate associated with admission during weekday out of hours compared with weekday office hours (risk difference 4.1% (95% CI 2.2%-6.1%) . For patients with anemia, there was more than a doubling in mortality for patients admitted during weekend nighttime hours compared to weekday office hours.

Table 3. Crude and age-and sex standardized 30-day mortality rates for 20 common medical conditions among acute medical patients by time of admission.

	Weekday			Weekend			
	Office hours (8.00 am-4.59 pm)	Out of hours (5.00 pm-7.59 am)		Day (9.00 am-9.59 pm)		Night (10.00 pm-8.59 am) plus Friday 10.00-11.59 pm and Monday 12.00 am - 7.59 am	
	Crude/reference n (%)	Crude n (%)	Standardized[a] % (95%CI)	Crude n (%)	Standardized[a] % (95% CI)	Crude n (%)	Standardized[a] % (95% CI)
Overall	4,501 (5.1)	2,210 (5.1)	5.7 (5.5-6.0)	1,821 (6.2)	6.4 (6.1-6.7)	765 (5.5)	6.3 (5.9-6.8)
Common medical conditions							
Infectious diseases							
Pneumonia	565 (9.60)	289 (10.3)	10.1 (9.04-11.2)	252 (11.5)	10.6 (9.39-11.8)	99 (10.1)	9.92 (8.10-11.7)
Erysipelas	16 (1.61)	8 (1.56)	1.76 (0.58-2.94)	6 (1.63)	2.11 (0.46-3.76)	2 (1.60)	2.33 (0.00-5.46)
Bacteremia/septicemia	248 (20.6)	153 (20.2)	20.1 (17.4-22.9)	111 (19.7)	18.9 (15.8-21.9)	63 (26.5)	27.1 (21.6-32.6)
Urinary Tract Infection	106 (5.45)	46 (4.62)	4.81 (3.47-6.15)	34 (4.59)	4.41 (2.98-5.84)	11 (3.67)	4.59 (1.98-7.21)
Hematological Diseases							
Anemia	104 (4.36)	26 (6.24)	6.51 (4.09-8.93)	21 (7.89)	8.04 (4.76-11.3)	8 (8.60)	9.24 (3.19-15.3)
Endocrine and nutritional disease							
Diabetes	25 (1.62)	9 (1.78)	1.68 (0.57-2.78)	9 (2.76)	2.51 (0.87-4.15)	2 (1.27)	1.16 (0.00-2.82)
Dehydration	230 (11.1)	105 (11.0)	11.3 (9.31-13.3)	87 (12.5)	12.4 (9.96-14.8)	21 (9.86)	10.3 (6.12-14.4)
Mental and behavioral disorders							
Alcohol intoxication	19 (1.92)	11 (1.11)	1.11 (0.45-1.77)	11 (1.98)	2.24 (0.95-3.52)	NA	NA
Diseases of the nervous system							
Transient Ischemic Attack	7 (0.51)	3 (0.37)	0.32 (0.00-0.68)	6 (0.99)	0.83 (0.16-1.50)	NA	NA
Diseases of the circulatory system							
Angina	39 (1.78)	10 (1.00)	1.13 (0.44-1.82)	9 (1.46)	1.52 (0.54-2.50)	11 (2.70)	2.90 (1.26-4.54)
Acute Myocardial Infarction	138 (6.06)	93 (7.06)	7.20 (5.83-8.58)	77 (7.72)	8.09 (6.43-9.76)	49 (7.06)	7.05 (5.18-8.92)
Atrial fibrillation	76 (2.05)	30 (2.56)	2.72 (1.77-3.66)	27 (3.04)	3.20 (2.02-4.38)	13 (3.67)	3.68 (1.75-5.61)
Heart failure	132 (8.02)	45 (8.41)	8.59 (6.22-11.0)	39 (13.0)	12.4 (8.73-16.1)	21 (10.1)	9.20 (5.50-12.9)
Hypertension	14 (1.19)	9 (1.85)	1.64 (0.63-2.66)	5 (1.52)	1.22 (0.17-2.26)	NA	NA
Stroke	293 (9.19)	211 (13.3)	13.4 (11.7-15.0)	178 (12.7)	12.2 (10.6-13.9)	59 (11.5)	11.9 (9.17-14.7)
Diseases of the respiratory system							
Chronic Obstructive Pulmonary Disorder	140 (4.88)	62 (4.87)	5.08 (3.85-6.32)	61 (6.59)	6.60 (5.02-8.19)	33 (6.06)	6.80 (4.53-9.07)
Respiratory failure	260 (23.2)	131 (23.4)	24.0 (20.5-27.5)	118 (28.5)	28.1 (23.8-32.3)	51 (22.8)	24.9 (19.1-30.6)
Diseases of the digestive system							
Gastroenteritis	17 (1.44)	5 (0.82)	1.02 (0.14-1.89)	14 (3.00)	3.23 (1.57-4.90)	5 (2.16)	2.74 (0.42-5.07)
Symptoms and abnormal findings							
Syncope	9 (0.58)	12 (1.00)	1.09 (0.48-1.70)	8 (0.92)	0.84 (0.26-1.41)	3 (0.89)	1.22 (0.00-2.55)
Factors influencing health status							
Suspected Acute Myocardial Infarction	25 (0.67)	17 (0.74)	1.00 (0.54-1.47)	16 (1.10)	1.11 (0.57-1.65)	6 (0.84)	0.97 (0.17-1.77)
Other	2,038 (4,55)	935 (4.15)	4.91 (4.61-5.21)	732 (5.17)	5.58 (5.19-5.96)	308 (4.45)	5.54 (4.94-6.13)

[a]**Standardized to the age- and gender distribution of the patients admitted during weekday office hours in each individual subgroup**

In the sensitivity analysis, which included age, sex, and the CCI score in the standardization of the 30-day mortality rates, similar results were found for the estimates in the overall cohort, as well as in the subgroups of common conditions. In our analysis of the subgroup of patients admitted through the emergency department, we identified no major differences in mortality rate or ICU admissions by time of admission (Appendix, Table S4). The admission rates varied with the lowest admission rate during weekend nighttime hours. The 30-day mortality rate for the medical patients who required acute admission during public holidays was 5.8% (95% CI 5.2-6.3) compared to 5.3% (95% CI 5.2-5.4) among the medical patients who required acute admission outside public holidays (weekend and weekdays).

DISCUSSION

Key findings

In this register-based cohort study, timing of first-time admissions varied and weekend admissions were associated with the highest proportion admitted to an ICU and the highest mortality for the majority of the conditions examined. By including weekday out of hours as a separate time of admission, we were able to discern important differences in patient characteristics, for example that the proportion of patients arriving through the emergency department changed dramatically from weekday office hours to weekday out of hours.

Strengths and limitations

The key strength of this cohort study was the use of a nationwide population-based medical registry that included all first-time acute admissions to departments of

medicine in Denmark. The population-based design essentially removes concerns about patient selection bias, and the CPR number assigned to all Danish residents permits unambiguous individual-level linkage among all Danish administrative and medical registries.

A concern is the accuracy of data on time of admission. While the administrative data has high accuracy in the DNRP, the accuracy of the registration of time of the day is unknown. Inaccurate registration of time of admission may introduce bias in our estimates, but we assume such bias to be minor as the intervals range over many hours thereby limiting the misclassification between two periods. In addition, registration of time of admission is registered prospectively, independent of future events such as death or ICU admission.

Administrative databases provide extensive and valuable data, but variation in coding practices is an inherent limitation.[26] Often an acute condition associate with a chronic condition and the extent of diagnostic work-up or complications during admission may influence coding practices.[23] The accuracy of some diagnoses in the DNRP is known. For example, diagnosis of chronic obstructive pulmonary disorder, non-specific diagnosis of syncope, and diagnosis of acute stroke have all been found to have reasonable high accuracy.[27-29] Similarly, the accuracy of diagnostic coding for the conditions in the CCI has also been shown to be high.[30] An ICU admission and the treatment provided during an ICU stay were identified with procedure codes and these variables have high accuracy.[31] Since we used a population-based registry to identify

large groups of patients diagnosed with same ICD-10 codes, we assume that misclassification bias had only a minor impact on our results, if any.

Interpretation

No previous studies have presented admission rates or changes in reasons for admission associated with time of admission. We found that hourly admission rates for the common conditions among acute medical patients vary between the different times of admission. This may both be explained by differences in disease occurrence, but also by organizational differences, which changes the threshold for admission. This is supported by a higher mortality rate associated with admission outside office hours for the majority of the conditions examined. An example is anemia, which demonstrated a tremendous decrease in admission rates outside weekday office hours. In patients with anemia the mortality rate and risk of an ICU admission more than doubled when patients were admitted during the weekend, which may infer an association to severity of the disease. In support of the hypothesis that more patients with severe illnesses are admitted during the weekend, previous studies on stroke, a common disorder that requires acute care, found that the “weekend effect” disappeared after adjusting for deferred admissions and disease severity. [32-34]

Although the Danish health care system differs from those in other countries, our study lends support to previous evidence of a higher mortality associated with an acute admission during the weekend but extends this by examining office hours versus out of hours, weekend daytime hours and weekend nighttime hours.[1-16] All earlier studies examined this effect by defining the weekend as starting on Friday at midnight

and ending on Sunday at midnight. A few studies have examined mortality associated with admissions during out of hours, but no studies of an overall cohort of acute patients have distinguished between weekday out of hours and weekend daytime and nighttime hours.[8,9] The limited availability of the patients' personal GP and specialized care at the hospitals are assumed to apply to both weekday out of hours, weekend hours and public holidays.

A few studies have examined the 24-hour variation in admission. Despite the different reasons for admissions, the overall admission pattern forms a curve with two peaks, one during the mid-morning hours and one during the late afternoon hours.[35-37] If this variation associates to a natural course of the diseases, a variation in prevalence and hence a variation in admission rates should be expected. However, this variation may more likely associate to the availability of the GPs.

A higher proportion of the patients arrived through the emergency department outside office hours. The reasons could be associated with availability of GPs for consultation, or it could be patient-related, associated with proportionally more patients with severe diseases presenting to departments of medicine outside office hours. A study from UK, which examined the referral rates of acute hospital admission from the GPs, found an increased referral rate outside office hours.[38]

Our study lacked clinical data on the severity of disease, but included information on the proportion of patients admitted to an ICU. We found a higher proportion of ICU admissions and organ supportive treatments during weekday out of hours and over the weekend compared to the weekday office hours. Our findings contrasted with

those from a previous US and a previous Australian study.[9,39] The US study was based on medical record reviews of 824 admissions to general medicine units. They found that weekend admissions were associated with a lower risk of ICU transfer.[9] Differences in ICU settings between countries must be acknowledged when making comparisons of ICU admission rates.[40]

We considered an ICU admission and ICU procedures as proxies for severity of illness, although we also acknowledge the limitations in this approximation. For example, the use of ICU procedures is highly associated with age.[41] Additionally, it is important to emphasize that some patients with severe illness will not be offered full therapy and that ICU admission also depends on bed availability. There are no national or European guidelines for admission and discharge to an ICU.

The present study may add important knowledge to healthcare planners about patient characteristics associated with admission outside office hours and the associated risk of ICU admission and death.

In conclusion, timing of first-time admissions varied and weekend admissions were associated with the highest proportion admitted to an ICU and the highest mortality for the majority of the conditions examined. By including weekday out of hours as a separate time of admission, we were able to discern important differences in patient characteristics.

Contributor statement:

BV-H, AHR, HTS, and CFC contributed to the study conception, design, and the interpretation of data. BV-H, AHR, HTS, and CFC were responsible for the acquisition of data. BV-H analyzed and drafted the manuscript. All authors critically revised the manuscript and approved the final version.

Competing interests:

The authors report no competing interest in conducting this study.

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Data sharing:

No additional unpublished data are available from the present study.

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Supplement to

Out of Hours and Weekend Admissions to Danish Medical Departments: Admission Rates and 30-Day Mortality for 20 Common Medical Conditions

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Table S1. ICD-10 diagnoses of common conditions among acute medical patients

Table S2. ICD-10 codes for the Charlson Comorbidity Index conditions

Table S3. ICU admissions within three days after admission in medical conditions among acute medical patients according to time of admission

Table S4. Admission rates, age-and-sex standardized 30-day mortality and ICU admission within three days after the index date for the patients admitted through the emergency room

Table S1. ICD-10 diagnoses of common conditions among acute medical patients

Pneumonia	J12-J18, A48.1, A70.9
Erysipelas	A46
Bacteremia/septicemia	A40-41, A02.1, A20.7, A21.7, A22.7, A22.9B, A26.7, A28.2, A32.7, A39.2-4, A42.7, A49.9A, A54.8G, B37.7, B49.9A, J95.0A
UTI	N30, N34, N39.0
Anemia	D50-64
Diabetes	E10-14
Dehydration	E86
Alcohol Intoxication	F10
Transient ischemic attack	G45
Angina	I20, I24, I25
AMI	I21
AFLI	I48
Heart Failure	I50, I11.0, I13.0, I13.2
Hypertension	I10, D15
Stroke	I60-61, I63-64
COPD	J40-44, J47
Respiratory failure	J96
Gastroenteritis	A0
Syncope	R55
Suspected AMI	Z03.4

Table S2. ICD-10 codes for the Charlson Comorbidity Index conditions

Charlson score of 1:	
Myocardial infarction	I21, I22, I23
Congestive heart failure	I50, I11.0, I13.0, I13.2
Peripheral vascular disease	I70, I71, I72, I73, I74, I77
Cerebrovascular disease	I60-I69, G45, G46
Dementia	F00-F03, F05.1, G30
Chronic pulmonary disease	J40-J47, J60-J67, J68.4, J70.1, J70.3, J84.1, J92.0, J96.1, J98.2, J98.3
Connective tissue disease	M05, M06, M08, M09, M30, M31, M32, M33, M34, M35, M36, D86
Ulcer disease	K22.1, K25-K28
Mild liver disease	B18, K70.0-K70.3, K70.9, K71, K73, K74, K76.0
Diabetes mellitus	E10.0-E10.2, E10.9, E11.0-E11.1, E11.9
Charlson score of 2:	
Hemiplegia	G81, G82
Diabetes with end organ damage	E10.2-E10.8, E11.2-E11.8
Any tumor	C00-C75
Leukemia	C91-C95
Lymphoma	C81-C85, C88, C90, C96
Charlson score of 3:	
Moderate to severe liver disease	B15.0, B16.0, B16.2, B19.0, K70.4, K72, K76.6, I85
Charlson score of 6:	
Metastatic solid tumor	C76-C80
AIDS	B21-B24

Table S3. ICU admissions within three days after admission in medical conditions among acute medical patients according to time of admission

	Weekday				Weekend			
	Office hours (8.00 am-4.59 pm)		Out of hours (5.00 pm-7.59 am)		Weekend daytime hours (9.00 am-9.59 pm)		Weekend nighttime hours (10.00 pm-8.59 am) plus Friday 10.00-11.59 pm and Monday 0.00-7.59 am	
	n	ICU admissions (% of group)	n	ICU admissions (% of group)	n	ICU admissions (% of group)	n	ICU admissions (% of group)
Infectious diseases								
Pneumonia	5,886	165 (2.8)	2,797	118 (4.2)	2,197	71 (3.4)	978	55 (5.6)
Erysipelas	991	2 (0.2)	513	2 (0.4)	367	1 (0.3)	125	1 (0.8)
Bacteremia/septicemia	1,201	132 (11.0)	759	84 (11.1)	563	68 (12.1)	238	29 (12.2)
Urinary Tract Infection	1,944	6 (0.3)	996	6 (0.6)	740	2 (0.3)	300	1 (0.3)
Hematological diseases								
Anemia	2,384	15 (0.6)	417	7 (1.7)	266	5 (2.0)	93	4 (4.3)
Endocrine and nutritional diseases								
Diabetes	1,540	52 (3.4)	507	31 (6.1)	326	28 (8.6)	158	18 (11.4)
Dehydration	2,073	8 (0.4)	953	7 (0.7)	697	3 (0.4)	213	0
Mental and behavioral disorders								
Alcohol intoxication	989	17 (1.7)	994	18 (1.8)	556	12 (2.2)	388	16 (4.1)
Diseases of the nervous system								
Transient ischemic attack	1,380	0	811	2 (0.3)	609	1 (0.2)	200	1 (0.5)
Diseases of the circulatory system								
Angina	2,191	25 (1.1)	1,000	14 (1.4)	616	11 (1.8)	408	7 (1.7)
Acute Myocardial Infarction	2,274	85 (3.7)	1,317	65 (4.9)	997	43 (4.3)	694	35 (5.0)
Atrial Fibrillation	3,707	23 (0.6)	1,170	8 (0.7)	889	4 (0.5)	354	2 (0.6)
Heart failure	1,645	27 (1.6)	535	29 (5.4)	300	13 (4.3)	207	12 (5.8)
Hypertension	1,173	3 (0.3)	487	3 (0.6)	329	1 (0.3)	136	1 (0.7)
Stroke	3,187	84 (2.6)	1,587	90 (5.7)	1,407	47 (3.3)	515	30 (5.8)
Diseases of the respiratory system								
Chronic Obstructive Pulmonary Disorder	2,869	91 (3.2)	1,273	65 (5.1)	926	42 (4.5)	545	37 (6.8)
Respiratory failure	1,120	152 (13.6)	559	74 (13.2)	414	81 (19.6)	224	38 (17.0)
Diseases of the digestive system								
Gastroenteritis	1,179	3 (0.3)	612	7 (1.1)	466	6 (1.3)	231	1 (0.4)
Symptoms and abnormal findings								
Syncope	1,554	4 (0.3)	1,195	8 (0.7)	865	3 (0.4)	336	3 (0.9)
Factors influencing health status								
Suspected Acute Myocardial Infarction	3,719	6 (0.2)	2,304	4 (0.2)	1,455	8 (0.6)	712	7 (1.0)
Other	44,758	860 (1.9)	22,5626	691 (3.1)	14,155	462 (3.3)	6,921	323 (4.7)
Total (within three days)	87,764	1,760 (2.0)	43,312	1,333 (3.1)	29,140	923 (3.2)	13,976	521 (4.4)
Total (complete length of hospital stay)		2,603 (3.0)		1,712 (4.0)		1,190 (4.1)		746 (5.3)

Table S4. Admission rates, age-and-sex standardized 30-day mortality and ICU admission within three days after the index date for the patients admitted through the emergency room

	Weekday		Weekend	
	Office hours (8.00 am-4.59 pm)	Out of hours (5.00 pm-7.59 am)	Weekend daytime hours (9.00 am-9.59 pm)	Weekend nighttime hours (10.00 pm-8.59 am) Friday 10.00-11.59 pm and Monday 0.00-7.59 am
Total (n)	13,225	14,492	8,810	4,618
Hourly admission rate	5.83 (5.73-5.93)	4.46 (4.39-4.53)	6.00 (5.87-6.12)	2.60 (2.53-2.68)
Crude Mortality Age- and sex- standardized mortality	5.87 (5.47-6.26)	4.80 5.51 (5.11-5.90)	5.86 6.19 (5.68-6.69)	4.79 5.95 (5.20-6.70)
ICU n (%)	622 (4.70)	657 (4.53)	448 (5.09)	266 (5.76)

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STROBE Statement—Checklist of items that should be included in reports of ***cohort studies***

	Item No	Recommendation	Page
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	2
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	2
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	4
Objectives	3	State specific objectives, including any prespecified hypotheses	5
Methods			
Study design	4	Present key elements of study design early in the paper	5
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	5
Participants	6	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up	6
		(*b*) For matched studies, give matching criteria and number of exposed and unexposed	
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	6-7
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	*6-7*
Bias	9	Describe any efforts to address potential sources of bias	7-8
Study size	10	Explain how the study size was arrived at	6
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	8
		(*b*) Describe any methods used to examine subgroups and interactions	9
		(*c*) Explain how missing data were addressed	
		(*d*) If applicable, explain how loss to follow-up was addressed	
		(*e*) Describe any sensitivity analyses	
Results			
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	9
		(b) Give reasons for non-participation at each stage	
		(c) Consider use of a flow diagram	
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	9-10
		(b) Indicate number of participants with missing data for each variable of interest	
		(c) Summarise follow-up time (eg, average and total amount)	
Outcome data	15*	Report numbers of outcome events or summary measures over time	13-17
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which	16

		confounders were adjusted for and why they were included	
		(*b*) Report category boundaries when continuous variables were categorized	
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	17
Discussion			
Key results	18	Summarise key results with reference to study objectives	17
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	17-18
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	18-19
Generalisability	21	Discuss the generalisability (external validity) of the study results	19
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	21

*Give information separately for exposed and unexposed groups.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at http://www.strobe-statement.org.

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Out of Hours and Weekend Admissions to Danish Medical Departments: Admission Rates and 30-Day Mortality for 20 Common Medical Conditions

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ORIGINAL RESEARCH

Out of Hours and Weekend Admissions to Danish Medical Departments: Admission Rates and 30-Day Mortality for 20 Common Medical Conditions

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Abstract

Objectives: Knowledge on the combined weekly and diurnal variation in timing of admissions and mortality for acute medical patients is limited. The aim of the study was to examine hospital admission rates and mortality rates for patients with common medical conditions according to time of admission.

Design: Nationwide population-based cohort study.

Setting: Population of Denmark.

Participants: Using the Danish National Registry of Patients (DNRP) covering all Danish hospitals, we identified all adults with the first acute admission to a medical department in Denmark during 2010. Readmissions and transfers were excluded.

Primary and secondary outcome measures: Hourly admission rates and age- and sex-standardized 30-day mortality rates comparing weekday office hours, weekday out of hours, weekend daytime hours, and weekend nighttime hours.

Results: In total, 174,192 acute medical patients were included in the study. The admission rates (patients per hour) were 38.7 (95% CI 38.4-38.9) during weekday office hours, 13.3 (95% CI 13.2-13.5) during weekday out of hours, 19.8 (95% CI 19.6-20.1) during weekend daytime hours, and 7.9 (95% CI 7.8-8.0) during weekend nighttime hours. Admission rates varied between medical conditions. The proportion admitted through the emergency department and to an intensive care unit (ICU) increased outside office hours. The age- and sex-standardized 30-day mortality rate was 5.1% (95% CI 5.0-5.3%) after admission during weekday office hours, 5.7% (95% CI 5.5-6.0%)

after admission during weekday out of hours, 6.4% (95% CI 6.1-6.7%) after admission during weekend daytime hours, and 6.3% (95% CI 5.9-6.8%) after admission during weekend nighttime hours. For the majority of the medical conditions examined, weekend admission was associated with highest mortality.

Conclusions: While admission rates decreased from office hours to weekend hours there was an observed increase in mortality. This may reflect differences in severity of illness as the proportion admitted to an ICU increased during the weekend.

ARTICLE SUMMARY

Strengths and limitations of this study

- This study is the first to analyze hourly admission rates and mortality rates associated with time of admission in 20 common conditions among acute medical patients in a population-based design
- We provide a subtle categorization of time of admission including both weekday office hours, weekday out of hours, weekend daytime hours and weekend nighttime hours
- Our study lacked clinical data on severity of disease and staffing level, but included information on the proportion admitted to intensive care units and the proportion receiving specific intensive care treatment according to time of admission.

INTRODUCTION

Acute hospital admission rate decreases during weekend, but an admission during weekend has been associated with higher in-hospital mortality, an association termed "the weekend effect".[1-16] The weekend effect has been observed among acutely hospitalized patients in differing healthcare systems, including Canada, the US, and Australia, as well as in European countries. Understanding the higher short-term mortality associated with weekend admissions is important both for clinicians and healthcare planners. Two possible explanations for the weekend effect are the changes in the availability of specialized care or changes in patient characteristics, *e.g.* disease severity.[17]

A more subtle categorization of time of admission in patients admitted during weekday office hours and out of hours, as well as daytime hours and nighttime hours during the weekend may clarify important differences in patient characteristics. Furthermore, admission rates for common medical conditions in these time periods may serve as a proxy of the changes in referral threshold and together with mortality rates add to the understanding of the weekend effect. Variation in timing of admission and mortality rates for common medical conditions has to our best knowledge not previously been examined. Previous studies examining "out of hours" and mortality have primarily investigated "out of hours" as the time outside regular hours/office hours, not distinguishing between "Office" and "Out of hours" hours during weekdays, as well as between daytime and nighttime hours of the weekend.[8-9]

We therefore examined the hourly admission rates and 30-day mortality rates for patients with 20 common medical conditions comparing weekday office hours, weekday out of hours, weekend daytime hours, and weekend nighttime hours in a cohort of acute medical patients with their first admission to departments of medicine during 2010 in Denmark.

METHODS

Study design and setting

In this register-based historic cohort study using prospectively collected data, we identified all acute hospital admissions to medical departments in Denmark between 1 January and 31 December 2010, as recorded in the Danish National Registry of Patients (DNRP). The DNRP is a central medical registry covering both public and private hospitals that record information on all hospital admissions to non-psychiatric hospitals since 1977 and all visits to emergency departments and hospital specialist clinics since 1995. The record of each admission or visit is linked to the unique CPR number. In the study period, the DNRP was managed by the National Board of Health, but is currently managed by Statens Serum Institut (SSI). After necessary approvals, data from the DNRP can be accessed by researchers in Denmark by application to SSI. In Denmark, the private hospitals account for less than 1% of the total number of beds and they do not provide acute care.[18]

General practitioners (GPs) have a key role in referring patients to the hospital departments since virtually all Danish residents are affiliated with a personal GP.

Outside regular office hours, GPs serve the patients from central regional clinics providing both phone service and consultation. Acute hospital admission is also available through a 1-1-2 emergency call, which provides ambulance service to the patient.[19] Finally, patients can present themselves to an emergency department on a 24-hour basis.[20] In the study period some emergency departments implemented a mandatory preadmission assessment based on a telephone call before arrival.

Denmark has a free, tax-funded health care system, which assures that all residents (5,534,738 million persons as of 1 January 2010) in both rural and urban areas have unrestricted and equal access to GPs and to specialist care in hospitals.[21,22]

Study population

The cohort, which included all patients with their first acute admission to medical departments in Denmark between 1 January and 31 December 2010, has previously been described.[23] For this present study, we excluded patients with an inpatient stay in a hospital department within the preceding 30 days or earlier on the day of admission.

Time of admission

Time of admission was defined as weekday office hours, weekday out of hours, weekend daytime hours, and weekend nighttime hours. Public holidays, *e.g.*, Easter and Christmas, were considered weekend days. Weekday office hours were from Monday to Friday from 8:00 am to 4:59 pm. Weekday out of hours were from Monday to Friday from 5:00 pm to 7:59 am, except Friday night from 10:00 pm-11:59 pm and Monday morning from 12:00 am to 7.59 am, which were considered part of the

weekend. Weekend daytime hours were Saturday and Sunday from 9:00 am to 9:59 pm. Weekend nighttime hours were Saturday and Sunday from 10:00 pm to 11:59 pm and from 12:00 am to 8:59 am plus Friday night from 10:00 pm to 11:59 pm, and Monday from 12:00 am to 7:59 am. Admission rates were computed hourly according to time of admission. An overall estimate of the admission rate per 100,000 citizen (>=15 years) was computed.

Mortality

Each Danish resident is assigned a unique personal identification number (CPR number) at birth or upon immigration by the Danish Civil Registration System (CRS).[24] Information on all-cause mortality within 30 days following the index date was captured by linking patients' CPR number to the CRS. The CRS was established in 1968 to collect and maintain information on vital status, marital status, residency, and migration for all residents of Denmark. The CRS thus contains complete up-to-date data on the vital status of all patients in our study. Patients were followed from their index date until death from any cause, emigration, or 30 days after the index date, whichever came first.

Patient characteristics

The DNRP provided the unique code for each hospital and department, admission type (*i.e*. acute), date of admission (*index date*), hour and minute of admission (00.00-23.59 hours), source of admission (hospital specialist clinic, emergency department, or direct referral), procedure codes for an intensive care unit (ICU) admission and specific intensive care treatment, date of discharge, and discharge diagnoses, with one primary

diagnosis reflecting the reason for admission and up to 19 secondary diagnoses, indicating additional chronic or acute diseases. Diagnoses were coded according to *the International Classification of Diseases*, version 10 (ICD-10).

By tabulation of the primary ICD-10 diagnoses assigned after the index admission, considered to be the main reason for admission, we identified 20 common conditions among acute medical patients, *i.e*. pneumonia, erysipelas, bacteremia/sepsis, urinary tract infection, anemia, diabetes, dehydration, alcohol intoxication, transient ischemic attack, angina, acute myocardial infarction, atrial fibrillation, heart failure, hypertension, stroke, chronic obstructive pulmonary disorder, respiratory failure, gastroenteritis, syncope, and suspected acute myocardial infarction (ICD-10 codes provided in Appendix, Table S1).

To capture clinically important morbidity, data on the 19 conditions included in the Charlson Comorbidity Index (CCI) were obtained from the DNRP for the five years preceding the index date (ICD-10 codes provided in Appendix, Table S2). The CCI score was divided in low (score of 0), moderate (score of 1-2), and high (score of 3 or higher). From CRS, data on marital status (married, never married, divorced, widowed, and unknown) were provided. We computed length of hospital stay as time from the index date to final hospital discharge, including in-hospital and inter-hospital transfers.

Statistical analysis

We classified patients as admitted during weekday office hours, weekday out of hours, weekend daytime hours, and weekend nighttime hours, and characterized them according to patient characteristics. The hourly admission rates and the 30-day

mortality rates were computed for the common medical conditions according to time of admission. To compute comparable 30-day mortality rates for different times of admission, we used direct standardization.[25] We applied the observed age- and sex-specific mortality rates to a standard population defined as the patients admitted during weekday office hours. That is, for each time period, we estimated what would have been the 30-day mortality rate in our standard population if the age- and sex-specific mortality rates equaled those of the time period of interest. In a sensitivity analysis, we included the CCI score in the standardization. We also reported the proportions of patients admitted to an ICU within three days following the index date and during the whole hospital stay. Additionally, we reported the proportions receiving specific intensive care treatment. An ICU admission serves as a proxy for the severity of the disease and of the availability of an ICU bed.

In a subgroup analysis, the admission rate, 30-day mortality rate, and ICU admissions during the four time periods were analyzed only among patients admitted through the emergency department. To acknowledge the effect from public holidays on our estimates, we analyzed the mortality rates associated with public holidays compared to all other days, including weekdays and weekend. We used direct standardization to the age and gender distribution of the study population admitted outside public holidays. Data were analyzed with the statistical software package STATA (version 11, Stata Corp., College Station, Texas, USA). The study was approved by the Danish Data Protection Agency (record number 1-16-02-1-08). Because the study was based solely on data from administrative and medical databases, no further approval from the Ethics Committee was required.

RESULTS

Patient characteristics

A total of 264,265 patients with an acute first-time admission to medical departments in Denmark during 2010 were registered. After excluding patients without residency in Denmark (n=505) and patients with a hospital admission within the preceding 30 days or on the day of the index admission (n=89,568), 174,192 patients were included in the study. Of these patients, 50.4% (n=87,764) were admitted during weekday office hours, 24.9% (n=43,312) during weekday out of hours, 16.7% (n=29,140) during weekend daytime hours, and 8.0% (n=13,976) during weekend nighttime hours. As shown in Table 1a, patients admitted during weekday office hours tended to be older and had slightly higher CCI scores than patients admitted during other time periods. Weekend nighttime hours were the only time of admission when males constituted the highest proportion of patients (50.8%). No major differences among patients were observed with regard to the individual CCI conditions. During weekday office hours, 15.1% were admitted through the emergency department, while 33.5% were admitted through the emergency department during weekday out of hours. Similarly, weekend daytime and weekend nighttime hours were associated with a high rate of admissions through the emergency department (30.2% and 33.0%, respectively).

Table 1a. Demographic and clinical characteristics of 174,192 patients with an acute admission to a department of medicine, by time of admission, Denmark, 2010.

	Weekday		Weekend	
	Office hours (8.00 am-4.59 pm)	Out of hours (5.00 pm-7.59 am)	Day (9.00 am -9.59 pm)	Night (10.00 pm-8.59 am) plus Friday 10.00-11.59 pm and Monday 12.00 am - 7.59 am
Overall	87,764 (50.4%)	43,312 (24.9%)	29,140 (16.7%)	13,976 (8.0%)
Age groups				
15-39	9,291 (10.6)	7,246 (16.7)	3,960 (13.6)	2,528 (18.1)
40-59	19,888 (22.7)	10,902 (25.2)	6,764 (23.2)	3,456 (24.7)
60-79	36,722 (41.8)	15,794 (36.5)	11,079 (38.0)	5,146 (36.8)
80+	21,863 (24.9)	9,370 (21.6)	7,337 (25.2)	2,846 (20.4)
Age, Median (years (IQR))	68 (54-79)	64 (47-78)	67 (51-80)	64 (46-77)
Gender				
Female	45,877 (52.3)	22,175 (51.2)	15,073 (51.7)	6,880 (49.2)
Male	41,887 (47.7)	21,1375 (48.8)	14,067 (48.3)	7,096 (50.8)
Charlson Comorbidity Index score				
0	49,384 (56.3)	25,710 (59.4)	16,647 (57.1)	8,055 (57.6)
1-2	27,302 (31.1)	12,687 (29.3)	8,996 (30.9)	4,267 (30.5)
3+	11,078 (12.6)	4,915 (11.4)	3,497 (12.0)	1,654 (11.8)
Presence of diseases included in the Charlson Comorbidity Index				
Myocardial infarction	3,246 (3.7)	1,658 (3.8)	1,117 (3.8)	590 (4.2)
Congestive heart failure	5,735 (6.5)	2,477 (5.7)	1,748 (6.0)	913 (6.5)
Peripheral vascular disease	4,683 (5.3)	1,926 (4.4)	1,388 (4.8)	686 (4.9)
Cerebrovascular disease	8,110 (9.2)	4,052 (9.3)	2,917 (10.0)	1,353 (9.8)
Dementia	1,920 (2.2)	1,013 (2.3)	769 (2.6)	296 (2.1)
Chronic pulmonary disease	9,934 (11.3)	4,758 (11.0)	3,296 (11.3)	1,691 (12.1)
Connective tissue disease	2,977 (3.4)	1,181 (2.7)	889 (3.1)	386 (2.8)
Ulcer disease	2,479 (2.8)	1,138 (2.6)	778 (2.7)	367 (2.6)
Mild liver disease	1,435 (1.6)	691 (1.6)	451 (1.6)	209 (1.5)
Diabetes without end-organ damage	7,154 (8.2)	3,362 (7.8)	2,268 (7.8)	1,099 (7.9)
Diabetes with end-organ damage	4,337 (4.9)	2,101 (4.9)	1,386 (4.8)	675 (4.8)
Hemiplegia	313 (0.4)	163 (0.4)	106 (0.4)	53 (0.4)
Moderate to severe renal disease	3,036 (3.5)	1,289 (3.0)	918 (3.2)	432 (3.1)
Non-metastatic solid tumor	7,555 (8.6)	3,157 (7.3)	2,393 (8.2)	1,032 (7.4)
Leukaemia	500 (0.6)	193 (0.5)	131 (0.5)	56 (0.4)
Lymphoma	874 (1.0)	354 (0.8)	270 (0.9)	107 (0.8)
Moderate to severe liver disease	511 (0.6)	202 (0.5)	159 (0.6)	85 (0.6)
Metastatic cancer	1,035 (1.2)	373 (0.9)	360 (1.2)	140 (1.0)
AIDS	152 (0.2)	85 (0.2)	50 (0.2)	23 (0.2)
Marital status				
Married	40,881 (46.6)	18,719 (43.2)	12,794 (43.9)	6,358 (45.5)
Never married	14,140 (16.1)	9,206 (21.3)	5,364 (18.4)	2,981 (21.3)
Divorced	12,414 (14.1)	6,486 (15.0)	4,230 (14.5)	2,064 (14.8)
Widowed	20,325 (23.2)	8,904 (20.6)	6,751 (23.2)	2,573 (18.4)
Unknown	4	0	1	0
Admission source				
Hospital outpatient specialist clinic	5,781 (6.6)	2,251 (5.2)	1,139 (3.9)	541 (3.9)
Emergency department	13,225 (15.1)	14,492 (33.5)	8,810 (30.2)	4,618 (33.0)
Other	69,438 (79.0)	27,343 (63.1)	19,610 (67.3)	8,997 (64.4)
Length of hospital stay [Median (days)]	3 (1-7)	2 (1-7)	3 (1-7)	3 (1-6)
Common medical conditions				
Pneumonia	5,886 (6.7)	2,797 (6.5)	2,197 (7.5)	978 (7.0)
Erysipelas	991 (1.1)	513 (1.2)	367 (1.3)	125 (0.9)
Bacteremia/Sepsis	1,201 (1.4)	759 (1.8)	563 (1.9)	238 (1.7)
Urinary tract infection	1,944 (2.2)	996 (2.3)	740 (2.5)	300 (2.2)
Anemia	2,384 (2.7)	417 (1.0)	266 (0.9)	93 (0.7)
Diabetes	1,540 (1.8)	507 (1.2)	326 (1.1)	158 (1.1)
Dehydration	2,073 (2.4)	953 (2.2)	697 (2.4)	213 (1.5)
Alcohol intoxication	989 (1.1)	994 (2.3)	556 (1.9)	388 (2.8)
Transient ischemic attack	1,380 (1.6)	811 (1.9)	609 (2.1)	200 (1.4)
Angina	2,191 (2.5)	1,000 (2.3)	616 (2.1)	408 (2.9)

Acute myocardial infarction	2,274 (2.6)	1,317 (3.0)	997 (3.4)	694 (5.0)
Atrial fibrillation	3,707 (4.2)	1,170 (2.7)	889 (3.1)	354 (2.5)
Heart failure	1,645 (1.9)	535 (1.2)	300 (1.0)	207 (1.5)
Hypertension	1,173 (1.3)	487 (1.1)	329 (1.1)	136 (1.0)
Stroke	3,187 (3.6)	1,587 (3.7)	1,407 (4.8)	515 (3.7)
Chronic obstructive pulmonary disorder	2,869 (3.3)	1,273 (2.9)	926 (3.2)	545 (3.9)
Respiratory failure	1,120 (1.3)	559 (1.3)	414 (1.4)	224 (1.6)
Gastroenteritis	1,179 (1.3)	612 (1.4)	466 (1.6)	231 (1.7)
Syncope	1,554 (1.8)	1,195 (2.8)	865 (3.0)	336 (2.4)
Suspected acute myocardial infarction	3,719 (4.2)	2,304 (5.3)	1,455 (5.0)	712 (5.1)
Other	44,758 (51.0)	22,526 (52.0)	14,155 (44.6)	6,921 (49.5)

Abbreviation: IQR= interquartile range

Table 1b. ICU admissions and ICU procedures

	Weekday		Weekend	
	Office hours (8.00 am-4.59 pm)	Out of hours (5.00 pm-7.59 am)	Day (9.00 am -9.59 pm)	Night (10.00 pm-8.59 am) plus Friday 10.00-11.59 pm and Monday 12.00 am - 7.59 am
	n (%)	n (%)	n (%)	n (%)
Total	87,764 (100)	43,312 (100)	29,140 (100)	13,976 (100)
ICU admissions	2603 (3.0)	1,712 (4.0)	1,190 (4.1)	746 (5.3)
ICU procedures				
Mechanical ventilation	1268 (1.4)	795 (1.8)	551 (1.9)	321 (2.3)
Non-invasive mechanical ventilation	634 (0.7)	369 (0.9)	259 (0.9)	159 (1.1)
Inotropes/vasopressor	1,024 (1.2)	624 (1.4)	443 (1.5)	260 (1.9)
Renal replacement therapy	229 (0.3)	136 (0.3)	94 (0.3)	53 (0.4)
Intensive care but no procedures	813 (0.9)	597 (1.4)	414 (1.4)	279 (2.0)

Abbreviations: ICU=Intensive Care Unit

Weekend nighttime hours were associated with the highest proportion of patients admitted to an ICU within the first three days (4.4%) compared to weekend daytime hours (3.2%), weekday out of hours (3.1%), and weekday office hours (2.0%) (Appendix, Table S3). For more than half of the individual medical conditions we examined, the highest risk of an ICU admission within three days after the index date was associated with an admission during weekend nighttime hours (Appendix, Table S3). For all 20 medical conditions except respiratory failure, admission weekday office hours were associated with the lowest risk of an ICU admission. In addition, we found that the proportion of patients receiving specific intensive care treatments, including mechanical ventilation, renal replacement therapy, and use of inotropes/vasopressors, was highest for the patients who were admitted during weekend nighttime hours. The proportion of the patients, who received multiple therapies was highest among the patients admitted outside office hours (Table 1b).

Admission rates

The admission rate during weekday office hours was 38.7 (95% Confidence Intervals (CI) 38.4-38.9) patients per hour, and corresponding figures were 13.3 (95% CI 13.2-13.5) during weekday out of hours, 19.8 (95% CI 19.6-20.1) during weekend daytime hours, and 7.9 (95% CI 7.8-8.0) during weekend nighttime hours (Table 2). The hourly admission rates per 100,000 citizen (>=15 years) in the four time periods were 0.91 (95% CI 0.87-0.95), 0.31 (95% CI 0.29-0.33), 0.47 (95% CI 0.43-0.50) and 0.19 (95% CI 0.17-0.21), respectively. Among the common medical conditions, pneumonia had the overall highest admission rate in all time periods. Anemia, diabetes, atrial fibrillation,

and heart failure had the relatively largest decreases in admission rates from weekday office hours to the other time periods while a condition like alcohol intoxication was associated with a more stable admission rate across time periods. The medical conditions with the lowest admission rates during weekend nighttime hours were anemia, erysipelas, diabetes, and hypertension.

Table 2. Hourly admission rates for 20 common medical conditions by time of admission.

	Weekday		Weekend	
	Office hours (8.00 am-4.59 pm)	Out of hours (5.00 pm-7.59 am)	Day (9.00 am-9.59 pm)	Night (10.00 pm-8.59 am) plus Friday 10.00-11.59 pm and Monday 12.00 am - 7.59 am
Overall	38.7 (38.4-38.9)	13.3 (13.2-13.5)	19.8 (19.6-20.1)	7.9 (7.8-8.0)
Common medical conditions				
Infectious diseases				
Pneumonia	2.60 (2.53-2.66)	0.86 (0.83-0.89)	1.50 (1.43-1.56)	0.55 (0.52-0.59)
Erysipelas	0.44 (0.41-0.47)	0.16 (0.14-0.17)	0.25 (0.22-0.28)	0.07 (0.06-0.08)
Bacteremia/septicemia	0.53 (0.50-0.56)	0.23 (0.22-0.25)	0.38 (0.35-0.42)	0.13 (0.12-0.15)
Urinary Tract Infection	0.86 (0.82-0.90)	0.31 (0.29-0.33)	0.50 (0.47-0.54)	0.17 (0.15-0.19)
Hematological Diseases				
Anemia	1.05 (1.01-1.09)	0.13 (0.12-0.14)	0.18 (0.16-0.20)	0.05 (0.04-0.06)
Endocrine and nutritional disease				
Diabetes	0.68 (0.65-0.71)	0.16 (0.14-0.17)	0.22 (0.20-0.25)	0.09 (0.08-0.10)
Dehydration	0.91 (0.88-0.95)	0.29 (0.27-0.31)	0.47 (0.44-0.51)	0.12 (0.10-0.14)
Mental and behavioral disorders				
Alcohol intoxication	0.44 (0.41-0.46)	0.31 (0.29-0.33)	0.38 (0.35-0.41)	0.22 (0.20-0.24)
Diseases of the nervous system				
Transient Ischemic Attack	0.61 (0.58-0.64)	0.25 (0.23-0.27)	0.41 (0.38-0.45)	0.11 (0.10-0.13)
Diseases of the circulatory system				
Angina	0.97 (0.93-1.01)	0.31 (0.29-0.33)	0.42 (0.39-0.45)	0.23 (0.21-0.25)
Acute Myocardial Infarction	1.00 (0.96-1.04)	0.41 (0.38-0.43)	0.68 (0.64-0.72)	0.39 (0.36-0.42)
Atrial fibrillation	1.63 (1.58-1.69)	0.36 (0.34-0.38)	0.61 (0.57-0.65)	0.20 (0.18-0.22)
Heart failure	0.73 (0.69-0.76)	0.16 (0.15-0.18)	0.20 (0.18-0.23)	0.12 (0.10-0.13)
Hypertension	0.52 (0.49-0.55)	0.15 (0.14-0.16)	0.22 (0.20-0.25)	0.08 (0.06-0.09)
Stroke	1.41 (1.36-1.45)	0.49 (0.46-0.51)	0.96 (0.91-1.01)	0.29 (0.27-0.32)
Diseases of the respiratory system				
Chronic Obstructive Pulmonary Disorder	1.26 (1.22-1.31)	0.39 (0.37-0.41)	0.63 (0.59-0.67)	0.31 (0.28-0.33)
Respiratory failure	0.49 (0.46-0.52)	0.17 (0.16-0.19)	0.28 (0.26-0.31)	0.13 (0.11-0.14)
Diseases of the digestive system				
Gastroenteritis	0.52 (0.49-0.55)	0.19 (0.17-0.20)	0.32 (0.29-0.35)	0.13 (0.11-0.15)
Symptoms and abnormal findings				
Syncope	0.69 (0.65-0.72)	0.37 (0.35-0.39)	0.59 (0.55-63)	0.19 (0.17-0.21)
Factors influencing health status				
Suspected Acute Myocardial Infarction	1.64 (1.59-1.69)	0.71 (0.68-0.74)	0.99 (0.94-1.04)	0.40 (0.37-0.43)
Other	19.7 (19.6-19.9)	6.93 (6.84-7.02)	9.64 (9.48-9.80)	3.90 (3.81-4.00)

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Mortality

Table 3 portrays the crude and age- and sex-standardized 30-day mortality rate for the common medical conditions. The age- and sex- standardized 30-day mortality rate was 5.1% (95% CI 5.0-5.3%) for patients admitted during weekday office hours, 5.7% (95%CI 5.5-6.0%) for patients admitted during weekday out of hours, 6.4% (95%CI 6.1-6.7%) for patients admitted during weekend daytime hours, and 6.3% (95%CI 5.9-6.8%) for patients admitted during weekend nighttime hours. The medical conditions with the highest mortality rate in all four time periods were respiratory failure and bacteremia/sepsis. In 17 of the 20 common medical conditions examined in this study, the highest mortality rate was associated with an admission during weekend, of which seven medical conditions had the highest mortality rate associated with weekend nighttime hours admission, *i.e.* erysipelas, bacteremia/sepsis, anemia, angina, atrial fibrillation, chronic obstructive pulmonary disorder, and syncope. Urinary tract infection was the only condition associated with the highest mortality rate for admissions during weekday office hours (Table 3) For patients admitted with hypertension or stroke, the highest mortality rate was associated with an admission during weekday out of hours. Notably, for patients with stroke there was a substantial increase in mortality rate associated with admission during weekday out of hours compared with weekday office hours (risk difference 4.1% (95% CI 2.2%-6.1%) . For patients with anemia, there was more than a doubling in mortality for patients admitted during weekend nighttime hours compared to weekday office hours.

Table 3. Crude and age-and sex standardized 30-day mortality rates for 20 common medical conditions among acute medical patients by time of admission.

	Weekday			Weekend			
	Office hours (8.00 am-4.59 pm)	Out of hours (5.00 pm-7.59 am)		Day (9.00 am-9.59 pm)		Night (10.00 pm-8.59 am) plus Friday 10.00-11.59 pm and Monday 12.00 am - 7.59 am	
	Crude/reference n (%)	Crude n (%)	Standardized[a] % (95%CI)	Crude n (%)	Standardized[a] % (95% CI)	Crude n (%)	Standardized[a] % (95% CI)
Overall	4,501 (5.1)	2,210 (5.1)	5.7 (5.5-6.0)	1,821 (6.2)	6.4 (6.1-6.7)	765 (5.5)	6.3 (5.9-6.8)
Common medical conditions							
Infectious diseases							
Pneumonia	565 (9.60)	289 (10.3)	10.1 (9.04-11.2)	252 (11.5)	10.6 (9.39-11.8)	99 (10.1)	9.92 (8.10-11.7)
Erysipelas	16 (1.61)	8 (1.56)	1.76 (0.58-2.94)	6 (1.63)	2.11 (0.46-3.76)	2 (1.60)	2.33 (0.00-5.46)
Bacteremia/septicemia	248 (20.6)	153 (20.2)	20.1 (17.4-22.9)	111 (19.7)	18.9 (15.8-21.9)	63 (26.5)	27.1 (21.6-32.6)
Urinary Tract Infection	106 (5.45)	46 (4.62)	4.81 (3.47-6.15)	34 (4.59)	4.41 (2.98-5.84)	11 (3.67)	4.59 (1.98-7.21)
Hematological Diseases							
Anemia	104 (4.36)	26 (6.24)	6.51 (4.09-8.93)	21 (7.89)	8.04 (4.76-11.3)	8 (8.60)	9.24 (3.19-15.3)
Endocrine and nutritional disease							
Diabetes	25 (1.62)	9 (1.78)	1.68 (0.57-2.78)	9 (2.76)	2.51 (0.87-4.15)	2 (1.27)	1.16 (0.00-2.82)
Dehydration	230 (11.1)	105 (11.0)	11.3 (9.31-13.3)	87 (12.5)	12.4 (9.96-14.8)	21 (9.86)	10.3 (6.12-14.4)
Mental and behavioral disorders							
Alcohol intoxication	19 (1.92)	11 (1.11)	1.11 (0.45-1.77)	11 (1.98)	2.24 (0.95-3.52)	NA	NA
Diseases of the nervous system							
Transient Ischemic Attack	7 (0.51)	3 (0.37)	0.32 (0.00-0.68)	6 (0.99)	0.83 (0.16-1.50)	NA	NA
Diseases of the circulatory system							
Angina	39 (1.78)	10 (1.00)	1.13 (0.44-1.82)	9 (1.46)	1.52 (0.54-2.50)	11 (2.70)	2.90 (1.26-4.54)
Acute Myocardial Infarction	138 (6.06)	93 (7.06)	7.20 (5.83-8.58)	77 (7.72)	8.09 (6.43-9.76)	49 (7.06)	7.05 (5.18-8.92)
Atrial fibrillation	76 (2.05)	30 (2.56)	2.72 (1.77-3.66)	27 (3.04)	3.20 (2.02-4.38)	13 (3.67)	3.68 (1.75-5.61)
Heart failure	132 (8.02)	45 (8.41)	8.59 (6.22-11.0)	39 (13.0)	12.4 (8.73-16.1)	21 (10.1)	9.20 (5.50-12.9)
Hypertension	14 (1.19)	9 (1.85)	1.64 (0.63-2.66)	5 (1.52)	1.22 (0.17-2.26)	NA	NA
Stroke	293 (9.19)	211 (13.3)	13.4 (11.7-15.0)	178 (12.7)	12.2 (10.6-13.9)	59 (11.5)	11.9 (9.17-14.7)
Diseases of the respiratory system							
Chronic Obstructive Pulmonary Disorder	140 (4.88)	62 (4.87)	5.08 (3.85-6.32)	61 (6.59)	6.60 (5.02-8.19)	33 (6.06)	6.80 (4.53-9.07)
Respiratory failure	260 (23.2)	131 (23.4)	24.0 (20.5-27.5)	118 (28.5)	28.1 (23.8-32.3)	51 (22.8)	24.9 (19.1-30.6)
Diseases of the digestive system							
Gastroenteritis	17 (1.44)	5 (0.82)	1.02 (0.14-1.89)	14 (3.00)	3.23 (1.57-4.90)	5 (2.16)	2.74 (0.42-5.07)
Symptoms and abnormal findings							
Syncope	9 (0.58)	12 (1.00)	1.09 (0.48-1.70)	8 (0.92)	0.84 (0.26-1.41)	3 (0.89)	1.22 (0.00-2.55)
Factors influencing health status							
Suspected Acute Myocardial Infarction	25 (0.67)	17 (0.74)	1.00 (0.54-1.47)	16 (1.10)	1.11 (0.57-1.65)	6 (0.84)	0.97 (0.17-1.77)
Other	2,038 (4,55)	935 (4.15)	4.91 (4.61-5.21)	732 (5.17)	5.58 (5.19-5.96)	308 (4.45)	5.54 (4.94-6.13)

[a]**Standardized to the age- and gender distribution of the patients admitted during weekday office hours in each individual subgroup**

In the sensitivity analysis, which included age, sex, and the CCI score in the standardization of the 30-day mortality rates, similar results were found for the estimates in the overall cohort, as well as in the subgroups of common conditions. In our analysis of the subgroup of patients admitted through the emergency department, we identified no major differences in mortality rate or ICU admissions by time of admission (Appendix, Table S4). The admission rates varied with the lowest admission rate during weekend nighttime hours. The 30-day mortality rate for the medical patients who required acute admission during public holidays was 5.8% (95% CI 5.2-6.3) compared to 5.3% (95% CI 5.2-5.4) among the medical patients who required acute admission outside public holidays (weekend and weekdays).

DISCUSSION

Key findings

In this register-based cohort study, timing of first-time admissions varied and weekend admissions were associated with the highest proportion admitted to an ICU and the highest mortality for the majority of the conditions examined. By including weekday out of hours as a separate time of admission, we were able to discern important differences in patient characteristics, for example that the proportion of patients arriving through the emergency department changed dramatically from weekday office hours to weekday out of hours.

Strengths and limitations

The key strength of this cohort study was the use of a nationwide population-based medical registry that included all first-time acute admissions to departments of

medicine in Denmark. The population-based design essentially removes concerns about patient selection bias, and the CPR number assigned to all Danish residents permits unambiguous individual-level linkage among all Danish administrative and medical registries.

A concern is the accuracy of data on time of admission. While the administrative data has high accuracy in the DNRP, the accuracy of the registration of time of the day is unknown. Inaccurate registration of time of admission may introduce bias in our estimates, but we assume such bias to be minor as the intervals range over many hours thereby limiting the misclassification between two periods. In addition, registration of time of admission is registered prospectively, independent of future events such as death or ICU admission.

Administrative databases provide extensive and valuable data, but variation in coding practices is an inherent limitation.[26] Often an acute condition associate with a chronic condition and the extent of diagnostic work-up or complications during admission may influence coding practices.[23] The accuracy of some diagnoses in the DNRP is known. For example, diagnosis of chronic obstructive pulmonary disorder, non-specific diagnosis of syncope, and diagnosis of acute stroke have all been found to have reasonable high accuracy.[27-29] Similarly, the accuracy of diagnostic coding for the conditions in the CCI has also been shown to be high.[30] An ICU admission and the treatment provided during an ICU stay were identified with procedure codes and these variables have high accuracy.[31] Since we used a population-based registry to identify

large groups of patients diagnosed with same ICD-10 codes, we assume that misclassification bias had only a minor impact on our results, if any.

Interpretation

No previous studies have presented admission rates or changes in reasons for admission associated with time of admission. We found that hourly admission rates for the common conditions among acute medical patients vary between the different times of admission. This may both be explained by differences in disease occurrence, but also by organizational differences, which changes the threshold for admission. This is supported by a higher mortality rate associated with admission outside office hours for the majority of the conditions examined. An example is anemia, which demonstrated a tremendous decrease in admission rates outside weekday office hours. In patients with anemia the mortality rate and risk of an ICU admission more than doubled when patients were admitted during the weekend, which may infer an association to severity of the disease. In support of the hypothesis that more patients with severe illnesses are admitted during the weekend, previous studies on stroke, a common disorder that requires acute care, found that the “weekend effect” disappeared after adjusting for deferred admissions and disease severity. [32-34]

Although the Danish health care system differs from those in other countries, our study lends support to previous evidence of a higher mortality associated with an acute admission during the weekend but extends this by examining office hours versus out of hours, weekend daytime hours and weekend nighttime hours.[1-16] All earlier studies examined this effect by defining the weekend as starting on Friday at midnight

and ending on Sunday at midnight. A few studies have examined mortality associated with admissions during out of hours, but no studies of an overall cohort of acute patients have distinguished between weekday out of hours and weekend daytime and nighttime hours.[8,9] The limited availability of the patients' personal GP and specialized care at the hospitals are assumed to apply to both weekday out of hours, weekend hours and public holidays.

A few studies have examined the 24-hour variation in admission. Despite the different reasons for admissions, the overall admission pattern forms a curve with two peaks, one during the mid-morning hours and one during the late afternoon hours.[35-37] If this variation associates to a natural course of the diseases, a variation in prevalence and hence a variation in admission rates should be expected. However, this variation may more likely associate to the availability of the GPs.

A higher proportion of the patients arrived through the emergency department outside office hours. The reasons could be associated with availability of GPs for consultation, or it could be patient-related, associated with proportionally more patients with severe diseases presenting to departments of medicine outside office hours. A study from UK, which examined the referral rates of acute hospital admission from the GPs, found an increased referral rate outside office hours.[38]

Our study lacked clinical data on the severity of disease, but included information on the proportion of patients admitted to an ICU. We found a higher proportion of ICU admissions and organ supportive treatments during weekday out of hours and over the weekend compared to the weekday office hours. Our findings contrasted with

those from a previous US and a previous Australian study.[9,39] The US study was based on medical record reviews of 824 admissions to general medicine units. They found that weekend admissions were associated with a lower risk of ICU transfer.[9] Differences in ICU settings between countries must be acknowledged when making comparisons of ICU admission rates.[40]

We considered an ICU admission and ICU procedures as proxies for severity of illness, although we also acknowledge the limitations in this approximation. For example, the use of ICU procedures is highly associated with age.[41] Additionally, it is important to emphasize that some patients with severe illness will not be offered full therapy and that ICU admission also depends on bed availability. There are no national or European guidelines for admission and discharge to an ICU.

The present study may add important knowledge to healthcare planners about patient characteristics associated with admission outside office hours and the associated risk of ICU admission and death.

In conclusion, while admission rates decreased from office hours to weekend hours, there was an observed increase in mortality rates when comparing admission during weekend hours with admission during office hours. This may be explained by differences in severity of illness as measured by the need for ICU admission.

Contributor statement:

BV-H, AHR, HTS, and CFC contributed to the study conception, design, and the interpretation of data. BV-H, AHR, HTS, and CFC were responsible for the acquisition of data. BV-H analyzed and drafted the manuscript. All authors critically revised the manuscript and approved the final version.

Competing interests:

The authors report no competing interest in conducting this study.

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Data sharing:

No additional unpublished data are available from the present study.

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Supplement to

Out of Hours and Weekend Admissions to Danish Medical Departments: Admission Rates and 30-Day Mortality for 20 Common Medical Conditions

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Table S1. ICD-10 diagnoses of common conditions among acute medical patients

Table S2. ICD-10 codes for the Charlson Comorbidity Index conditions

Table S3. ICU admissions within three days after admission in medical conditions among acute medical patients according to time of admission

Table S4. Admission rates, age-and-sex standardized 30-day mortality and ICU admission within three days after the index date for the patients admitted through the emergency room

Table S1. ICD-10 diagnoses of common conditions among acute medical patients

Pneumonia	J12-J18, A48.1, A70.9
Erysipelas	A46
Bacteremia/septicemia	A40-41, A02.1, A20.7, A21.7, A22.7, A22.9B, A26.7, A28.2, A32.7, A39.2-4, A42.7, A49.9A, A54.8G, B37.7, B49.9A, J95.0A
UTI	N30, N34, N39.0
Anemia	D50-64
Diabetes	E10-14
Dehydration	E86
Alcohol Intoxication	F10
Transient ischemic attack	G45
Angina	I20, I24, I25
AMI	I21
AFLI	I48
Heart Failure	I50, I11.0, I13.0, I13.2
Hypertension	I10, D15
Stroke	I60-61, I63-64
COPD	J40-44, J47
Respiratory failure	J96
Gastroenteritis	A0
Syncope	R55
Suspected AMI	Z03.4

Table S2. ICD-10 codes for the Charlson Comorbidity Index conditions

Charlson score of 1:	
Myocardial infarction	I21, I22, I23
Congestive heart failure	I50, I11.0, I13.0, I13.2
Peripheral vascular disease	I70, I71, I72, I73, I74, I77
Cerebrovascular disease	I60-I69, G45, G46
Dementia	F00-F03, F05.1, G30
Chronic pulmonary disease	J40-J47, J60-J67, J68.4, J70.1, J70.3, J84.1, J92.0, J96.1, J98.2, J98.3
Connective tissue disease	M05, M06, M08, M09, M30, M31, M32, M33, M34, M35, M36, D86
Ulcer disease	K22.1, K25-K28
Mild liver disease	B18, K70.0-K70.3, K70.9, K71, K73, K74, K76.0
Diabetes mellitus	E10.0-E10.2, E10.9, E11.0-E11.1, E11.9
Charlson score of 2:	
Hemiplegia	G81, G82
Diabetes with end organ damage	E10.2-E10.8, E11.2-E11.8
Any tumor	C00-C75
Leukemia	C91-C95
Lymphoma	C81-C85, C88, C90, C96
Charlson score of 3:	
Moderate to severe liver disease	B15.0, B16.0, B16.2, B19.0, K70.4, K72, K76.6, I85
Charlson score of 6:	
Metastatic solid tumor	C76-C80
AIDS	B21-B24

Table S3. ICU admissions within three days after admission in medical conditions among acute medical patients according to time of admission

	Weekday				Weekend			
	Office hours (8.00 am-4.59 pm)		Out of hours (5.00 pm-7.59 am)		Weekend daytime hours (9.00 am-9.59 pm)		Weekend nighttime hours (10.00 pm-8.59 am) plus Friday 10.00-11.59 pm and Monday 0.00-7.59 am	
	n	ICU admissions (% of group)	n	ICU admissions (% of group)	n	ICU admissions (% of group)	n	ICU admissions (% of group)
Infectious diseases								
Pneumonia	5,886	165 (2.8)	2,797	118 (4.2)	2,197	71 (3.4)	978	55 (5.6)
Erysipelas	991	2 (0.2)	513	2 (0.4)	367	1 (0.3)	125	1 (0.8)
Bacteremia/septicemia	1,201	132 (11.0)	759	84 (11.1)	563	68 (12.1)	238	29 (12.2)
Urinary Tract Infection	1,944	6 (0.3)	996	6 (0.6)	740	2 (0.3)	300	1 (0.3)
Hematological diseases								
Anemia	2,384	15 (0.6)	417	7 (1.7)	266	5 (2.0)	93	4 (4.3)
Endocrine and nutritional diseases								
Diabetes	1,540	52 (3.4)	507	31 (6.1)	326	28 (8.6)	158	18 (11.4)
Dehydration	2,073	8 (0.4)	953	7 (0.7)	697	3 (0.4)	213	0
Mental and behavioral disorders								
Alcohol intoxication	989	17 (1.7)	994	18 (1.8)	556	12 (2.2)	388	16 (4.1)
Diseases of the nervous system								
Transient ischemic attack	1,380	0	811	2 (0.3)	609	1 (0.2)	200	1 (0.5)
Diseases of the circulatory system								
Angina	2,191	25 (1.1)	1,000	14 (1.4)	616	11 (1.8)	408	7 (1.7)
Acute Myocardial Infarction	2,274	85 (3.7)	1,317	65 (4.9)	997	43 (4.3)	694	35 (5.0)
Atrial Fibrillation	3,707	23 (0.6)	1,170	8 (0.7)	889	4 (0.5)	354	2 (0.6)
Heart failure	1,645	27 (1.6)	535	29 (5.4)	300	13 (4.3)	207	12 (5.8)
Hypertension	1,173	3 (0.3)	487	3 (0.6)	329	1 (0.3)	136	1 (0.7)
Stroke	3,187	84 (2.6)	1,587	90 (5.7)	1,407	47 (3.3)	515	30 (5.8)
Diseases of the respiratory system								
Chronic Obstructive Pulmonary Disorder	2,869	91 (3.2)	1,273	65 (5.1)	926	42 (4.5)	545	37 (6.8)
Respiratory failure	1,120	152 (13.6)	559	74 (13.2)	414	81 (19.6)	224	38 (17.0)
Diseases of the digestive system								
Gastroenteritis	1,179	3 (0.3)	612	7 (1.1)	466	6 (1.3)	231	1 (0.4)
Symptoms and abnormal findings								
Syncope	1,554	4 (0.3)	1,195	8 (0.7)	865	3 (0.4)	336	3 (0.9)
Factors influencing health status								
Suspected Acute Myocardial Infarction	3,719	6 (0.2)	2,304	4 (0.2)	1,455	8 (0.6)	712	7 (1.0)
Other	44,758	860 (1.9)	22,5626	691 (3.1)	14,155	462 (3.3)	6,921	323 (4.7)
Total (within three days)	87,764	1,760 (2.0)	43,312	1,333 (3.1)	29,140	923 (3.2)	13,976	521 (4.4)
Total (complete length of hospital stay)		2,603 (3.0)		1,712 (4.0)		1,190 (4.1)		746 (5.3)

Table S4. Admission rates, age-and-sex standardized 30-day mortality and ICU admission within three days after the index date for the patients admitted through the emergency room

	Weekday		Weekend	
	Office hours (8.00 am-4.59 pm)	Out of hours (5.00 pm-7.59 am)	Weekend daytime hours (9.00 am-9.59 pm)	Weekend nighttime hours (10.00 pm-8.59 am) Friday 10.00-11.59 pm and Monday 0.00-7.59 am
Total (n)	13,225	14,492	8,810	4,618
Hourly admission rate	5.83 (5.73-5.93)	4.46 (4.39-4.53)	6.00 (5.87-6.12)	2.60 (2.53-2.68)
Crude Mortality Age- and sex- standardized mortality	5.87 (5.47-6.26)	4.80 5.51 (5.11-5.90)	5.86 6.19 (5.68-6.69)	4.79 5.95 (5.20-6.70)
ICU n (%)	622 (4.70)	657 (4.53)	448 (5.09)	266 (5.76)

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STROBE Statement—Checklist of items that should be included in reports of ***cohort studies***

	Item No	Recommendation	Page
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	2
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	2
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	4
Objectives	3	State specific objectives, including any prespecified hypotheses	5
Methods			
Study design	4	Present key elements of study design early in the paper	5
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	5
Participants	6	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up	6
		(*b*) For matched studies, give matching criteria and number of exposed and unexposed	
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	6-7
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	*6-7*
Bias	9	Describe any efforts to address potential sources of bias	7-8
Study size	10	Explain how the study size was arrived at	6
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	8
		(*b*) Describe any methods used to examine subgroups and interactions	9
		(*c*) Explain how missing data were addressed	
		(*d*) If applicable, explain how loss to follow-up was addressed	
		(*e*) Describe any sensitivity analyses	
Results			
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	9
		(b) Give reasons for non-participation at each stage	
		(c) Consider use of a flow diagram	
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	9-10
		(b) Indicate number of participants with missing data for each variable of interest	
		(c) Summarise follow-up time (eg, average and total amount)	
Outcome data	15*	Report numbers of outcome events or summary measures over time	13-17
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which	16

		confounders were adjusted for and why they were included	
		(*b*) Report category boundaries when continuous variables were categorized	
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	17
Discussion			
Key results	18	Summarise key results with reference to study objectives	17
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	17-18
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	18-19
Generalisability	21	Discuss the generalisability (external validity) of the study results	19
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	21

*Give information separately for exposed and unexposed groups.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at http://www.strobe-statement.org.