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Geographical variation in use of intensive care: a nationwide study

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Abstract *Purpose:* To examine whether there is geographical variation in the use of intensive care resources in Denmark concerning both intensive care unit (ICU) admission and use of specific interventions. Substantial variation in use of intensive care has been reported between countries and within the US, however, data on geographical variation in use within more homogenous tax-supported health care systems are sparse. *Methods:* We conducted a population-based cross-sectional study based on linkage of national medical registries including all Danish residents between 2008 and 2012 using population statistics from Statistics Denmark. Data on ICU admissions and interventions, including mechanical ventilation, noninvasive ventilation, acute renal replacement therapy, and treatment with inotropes/vasopressors, were obtained from the Danish Intensive Care Database. Data on patients' residence at the time of admission were obtained from the Danish National Registry of Patients. *Results:* The overall age- and gender standardized number of ICU patients per 1000 person-years for the 5-year period was 4.3 patients (95 % CI, 4.2; 4.3) ranging from 3.7 (95 % CI, 3.6; 3.7) to 5.1 patients per 1000 person-years (95 % CI, 5.0; 5.2) in the five regions of Denmark and from 2.8 (95 % CI, 2.8; 3.0) to 23.1 patients per 1000 person-years (95 % CI, 13.0; 33.1) in the 98 municipalities. The age-, gender-, and comorbidity standardized proportion of use of interventions among ICU patients also differed across regions and municipalities. *Conclusions:* There was only minimal geographical variation in the use of intensive care admissions and interventions at the regional level in Denmark, but more pronounced variation at the municipality level.

Keywords Critical care · Intensive care units · Patient admission · Geographical variation

Introduction

Intensive care is costly and constitutes a high proportion of healthcare costs [1]. Given the limited resources in the healthcare system, there has been continuous debate about the capacity and access to intensive care units (ICU) since studies show large variation between countries [2, 3]. This may be explained by lack of well-defined triage criteria in Europe. Beside the severity of illness and chronic diseases, differences in the available financial resources may

have significant impact on triage decisions, as well as factors related to the organization of the healthcare system including number of nurses and thus level of monitoring and care of critically ill patients in the regular wards [4–6].

We hypothesize that the tax-supported healthcare system in Denmark shows limited variation in the use of intensive care compared to previous US studies with more diverse healthcare systems [7]. Knowledge about any geographical variation in use of intensive care in a homogenous healthcare system like Denmark may provide further insight into the extent and nature of variation in use of intensive care [8].

We examined geographical variation between regions and municipalities in Denmark with regard to the number of ICU patients per inhabitants and the proportion of ICU patients receiving specific types of interventions.

Methods

Study design and setting

We conducted a nationwide cross-sectional study among all patients who were residents in Denmark from 2008 to 2012 using population statistics from Statistics Denmark [9].

Denmark is divided into 98 municipalities, which are local administrative bodies responsible for home nursing, public healthcare, and rehabilitation. In addition, five regions are responsible for the hospitals and the practice sector. The hospitals are funded similarly according to Diagnosis Related Groups (DRG). It is possible for the regions to organize services within financial and national legal limits according to local needs, including hospital staff and equipment at the hospitals.

The Ministry of Health and Prevention is the state's health authority, which is responsible for legislation on healthcare that covers the healthcare-related tasks of the regions and the municipalities [10].

Tax-supported healthcare is provided to all Danish residents, including access to public hospitals, where all intensive care is provided.

Intensive care unit admission and interventions

We used the Danish Intensive Care Database (DID) to identify all patients admitted for intensive care as well as specific interventions (mechanical ventilation, non-invasive ventilation, acute renal replacement therapy, and treatment with inotropes/vasopressors) in the 2008–2012 period.

The DID is a nationwide clinical quality database, which holds data on intensive care admissions from all ICUs ($n = 49$ in 2011). The DID was established in 2007 by the Danish Society of Intensive Care Medicine and the Danish Society of Anaesthesiology and Intensive Care Medicine [11, 12]. The database is approved by Danish Health and Medicines Authority and by the Danish Data Protection Agency, and it is mandatory by law for departments of intensive care to report to the database. Data are collected through hospital information systems, electronically transferred to the Danish National Registry of Patients (NRP), and subsequently retrieved by the DID. The positive predictive value of the coding of intensive care admissions in the NRP based on a sample of 150 intensive care admissions has been reported to be 97.3 % [13]. In addition, Blichert-Hansen et al. have examined the accuracy of coding of 150 ICU admissions and the individual intensive care interventions and found it to be close to 100 % [14]. The estimated completeness for DID is 95 % based on comparison with local patient data management systems [15].

Residency

We identified the patients' residence at time of hospital admission using the NRP. The NRP was established in 1977 and holds data from all hospitals including dates of all admissions and discharges, discharge diagnoses, surgical procedures, and patients' residences [16].

Patient characteristics

Covariates included age, gender, and comorbidity level according to the Charlson comorbidity index (CCI) [17], comprising 19 conditions including myocardial infarction, diabetes, and chronic pulmonary disease, which are selected and weighted according to their potential influence on mortality. The CCI was computed using all hospital diagnoses based on data from the NRP, including diagnoses from hospital admissions since 1977 and outpatient clinic and emergency room diagnoses since 1995. The weights of the 19 conditions were summed to a score and divided into three groups (1, 2, $\geq$3).

Statistical methods

First, we tabulated age, gender, CCI score, number of ICU beds (retrieved from the DID year report 2011 [15]), length of ICU stays (LOS), ICU bed-hours (LOS multiplied by ICU patients per 1000 person-years), and 30-day mortality by region.

Secondly, we estimated the number of ICU patients per 1000 person-years both annually and for the entire study period (2008–2012) as the number of patients' first admission within the 5-year period divided by the number

of residents on January 1st in the year of interest, as every person then counted 1 person-year. The denominator of the overall estimates was computed by the sum of the annually counted person-years for the 5-year study period.

The number of patients admitted to an ICU per 1000 person-years was computed for the whole country as well as separately for the five regions and 98 municipalities.

Additional analyses were conducted after excluding patients younger than 15 years old.

We used direct standardization to account for differences in age and gender between geographical areas by an annual standard for each of the years 2008–2012, covering the entire Danish population. We did not consider comorbidity in this analysis, as this information is only available for ICU patients and not for the general population.

As supplementary analysis, we also computed the total number of ICU admissions per 1000 person-years and the number of ICU admissions with mechanical ventilation per 1000 person-years.

Furthermore, we computed the proportion of ICU patients receiving mechanical ventilation, non-invasive ventilation, acute renal replacement therapy, or treatment with inotropes/vasopressors, and the proportion receiving none of the interventions. We standardized the proportions of patients receiving interventions to account for geographical differences in age, gender, and CCI [17] using an annual standard for each of the years 2008–2012.

Results

We identified 117,370 patients who were admitted to ICUs within a population representing 26,009,602 person-years. As shown in Table 1, there was only small variation of age and gender of the ICU patients across the regions. In contrast, the distribution of the CCI showed some variation between the regions with the North Denmark Region having the lowest proportion of patients with severe comorbidity (i.e., CCI level 3+) with 21.3 % and the Zealand Region the highest proportion of patients with 26.4 % (Table 1).

Some variation was observed regarding the ICU bed capacity. The Zealand Region had the lowest capacity with 5.9, whereas the Central Denmark Region had the highest number of ICU beds per 100,000 inhabitants with 7.8 [15] (Table 1).

The national median and mean LOS were 22.7 and 56.0 h, respectively. The median LOS in the regions ranged from 19.4 h in the Capital Region to 24.2 h in the region of Southern Denmark, whereas the mean ranged from 43.1 h in the Zealand Region to 68.1 h in the region of Southern Denmark. Additionally, the ICU bed-hours per 1000 person-years ranged from 187.5 bed-hours in the Zealand Region to 311.8 bed-hours in the North Denmark Region (Table 1).

The overall mortality within 30 days after admission to an ICU was 14 %. The mortality also varied among the regions from 10 % in Central Denmark Region to 17 % in the Capital Region.

Table 1 Characteristics of patients admitted to intensive care units in Denmark between 2008 and 2012

Patient characteristics	Denmark	Regions				
		North Denmark	Central Denmark	Southern Denmark	Capital	Zealand
Age						
25th percentile	48.0	44.0	44.0	51.0	49.0	50.0
Median	64.0	63.0	63.0	65.0	64.0	64.0
75th percentile	74.0	74.0	74.0	75.0	74.0	74.0
Gender, *n* (%)						
Female	50,563 (43.1)	6758 (43.9)	12,322 (43.8)	10,903 (42.0)	12,673 (43.3)	7980 (42.8)
Male	66,807 (56.9)	8648 (56.1)	15,824 (56.2)	15,044 (58.0)	16,618 (56.7)	10,678 (57.2)
Charlson comorbidity index score level, *n* (%)						
0	46,062 (39.2)	6640 (43.1)	11,644 (41.4)	9441 (36.4)	11,394 (38.9)	6943 (37.2)
1	22,480 (19.1)	2918 (19.0)	5319 (18.9)	5095 (19.6)	5591 (19.1)	3557 (19.1)
2	19,724 (16.8)	2562 (16.6)	4400 (15.6)	4686 (18.1)	4839 (16.5)	3237 (17.4)
3+	29,177 (24.8)	3281 (21.3)	6783 (24.1)	6725 (25.9)	7467 (25.5)	4921 (26.4)
ICU beds per 100,000 inhabitants (2011) [15]	7.2	7.2	7.8	7.1	7.5	5.9
Length of stay, hours						
25th percentile	10.5	11.8	9.9	14.9	2.6	11.7
Median	22.7	22.2	21.9	24.2	19.4	23.3
75th percentile	53.5	47.6	48.2	58.3	52.8	65.9
Length of stay, hours						
Mean	56.0	60.9	47.9	68.1	53.2	43.1
ICU bed-hours per 1000 person-years	238.0	311.8	220.8	284.7	195.8	187.5
30-day mortality, *n* (%)	14,991 (14)	1761 (12)	2811 (10)	2964 (12)	4757 (17)	2698 (16)

Table 2 Standardized number of ICU patients per 1000 person-years and standardized percentages of interventions in ICUs for the 5-year period 2008–2012

	Denmark	Regions				
		North Denmark	Central Denmark	Southern Denmark	Capital	Zealand
ICU patients per 1000 person-years[a] (95 % CI)	4.3 (4.2; 4.3)	5.1 (5.0; 5.2)	4.6 (4.6; 4.7)	4.2 (4.1; 4.2)	3.7 (3.6; 3.7)	4.4 (4.3; 4.4)
Mechanical ventilation[b], % (95 % CI)	41 (41; 41)	43 (42; 44)	37 (37; 38)	41 (40; 42)	45 (44; 46)	39 (38; 39)
Non-invasive ventilation[b], % (95 % CI)	12 (12; 13)	9 (8; 9)	12 (12; 13)	15 (14; 15)	12 (12; 12)	14 (14; 15)
Acute renal replacement therapy[b], % (95 % CI)	6 (6; 6)	5 (4; 5)	5 (5; 6)	6 (6; 6)	8 (7; 8)	6 (6; 7)
Inotropes/vasopressors[b], % (95 % CI)	33 (33; 33)	34 (33; 35)	31 (31; 32)	38 (37; 38)	31 (30; 32)	33 (32; 33)

[a] Age- and gender-standardized
[b] Age-, gender-, and comorbidity-standardized

Variation in number of patients admitted to ICU

The overall standardized number of ICU patients per 1000 person-years in Denmark for the 5-year period 2008–2012 was 4.3 patients per 1000 person-years (95 % CI 4.2; 4.3) (Table 2). Among the regions, the population of the Capital Region had lowest standardized number of ICU patients with 3.7 per 1000 person-years (95 % CI 3.6; 3.7), whereas North Denmark Region had the highest number with 5.1 patients per 1000 person-years (95 % CI 5.0; 5.2) (Table 2).

The variation in standardized number of ICU patients per 1000 person-years among the municipalities for the 5-year period is illustrated in Fig. 1 and ranged from 2.8 (95 % CI 2.6; 3.0) to 23.1 patients per 1000 person-years (95 % CI 13.0; 33.1).

The annual standardized number of ICU patients per 1000 person-years did not differ considerably within the 2008–2012 period and did not show substantial annual variation among the regions (Table 3 in the electronic supplementary material (ESM)).

Number of ICU patients of 15 years or older (ESM, Table 4) as well as analyses based on number of ICU admissions rather than patients (ESM, Table 5) did not differ substantially from the primary analyses.

Variation in use of intensive care interventions

For the 5-year period (2008–2012), the overall proportions of ICU admissions treated with mechanical ventilation, non-invasive ventilation, acute renal replacement therapy, inotropes/vasopressors, or none of these interventions were 41, 12, 6, 33, and 10 %, respectively (Table 2).

For mechanical ventilation the standardized proportion among the regions ranged from 37 % (95 % CI 37; 38) in Central Denmark Region to 45 % (95 % CI 45; 46) in Capital Region (Table 2).

The variation in use of mechanical ventilation across regions and municipalities is illustrated in Fig. 2 (ESM, Table 6).

The overall standardized proportion of admissions with mechanical ventilation per 1000 person-years in the 5-year period was 1.9 (95 % CI 1.9; 1.9) ranging from 1.8 (95 % CI 1.8; 1.8) to 2.3 (2.2; 2.4) in the regions (ESM, Table 7).

The use of non-invasive ventilation within the 5-year period ranged among regions from 9 % (95 % CI 8; 9) to 15 % (95 % CI 14; 15) of ICU patients, whereas the corresponding proportions for acute renal replacement therapy were 5 % (95 % CI 5; 5) to 8 % (95 % CI 7; 8) (Table 2). Treatment with inotropes/vasopressors varied from 31 % (95 % CI 30; 32) to 38 % (95 % CI 37; 38) across regions (Table 2). As for mechanical ventilation, we also found variation across municipalities for use of non-invasive ventilation, acute renal replacement therapy, and treatment with inotropes/vasopressors (ESM, Tables 8–10).

Discussion

We found geographical variation in intensive care admissions in Denmark, which could not be explained by differences in age and gender. Furthermore, we also found variation in use of intensive care interventions among ICU patients.

This study is to our knowledge the first nationwide study of geographical variation in a tax-supported healthcare system with universal coverage. Previous studies have reported variation in use of intensive care between countries and between US states [2, 3, 7].

A study of eight countries' use of intensive care showed major differences between the countries in number of ICU beds and volume of admissions for adult patients, ranging from 2.16 ICU admissions per year per

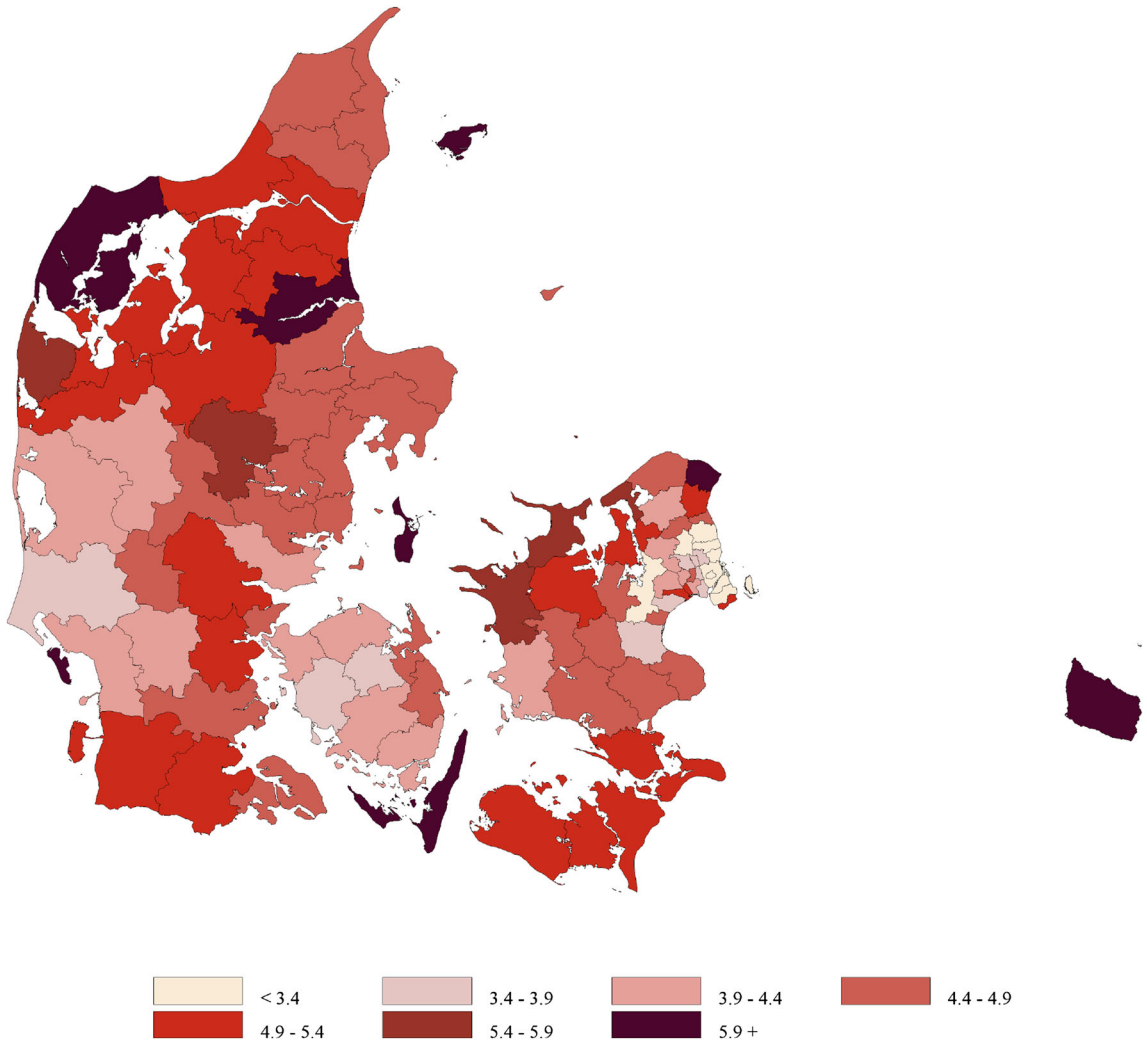

Fig. 1 Standardized number of ICU patients per 1000 person-years for the various municipalities of Denmark in the 5-year period between 2008–2012 (contains data from the Danish Geodata Agency and Danish municipalities)

1000 inhabitants in the UK to 23.53 ICU admissions per year per 1000 inhabitants in Germany [3]. In comparison we found 4.3 ICU patients per 1000 person-years in Denmark.

Another study suggested that variation in use of intensive care between the US and UK is caused by lower ICU bed availability in the UK, which was associated with fewer direct admissions from the emergency room, longer hospital stays before ICU admission, and higher severity of illness scores when admitted compared to in the US [2]. Such differences in care patterns and triage criteria may (although on a smaller scale) also be present between the regions of Denmark according to our study. However, the number of ICU beds per inhabitant in Denmark did not vary as much as among European countries, ranging from 4.2 to 29.2 ICU beds per 100,000 inhabitants [18].

On the basis of the available data we may only speculate on the reasons for the observed differences between regions in Denmark and it is beyond the scope of the current paper to disentangle the specific factors contributing to the variation. However, several factors could play a role including differences in capacity of ICUs and regular wards, differences in clinical practice and culture, differences in composition of the population and their morbidity patterns together with differences in registration and triage criteria for admission of an ICU patient.

Even within Denmark's uniform healthcare system, hospitals have different capacity both concerning ICUs and regular wards. It could be hypothesized that the number of patients admitted to ICUs and thereby admission decisions may vary depending on bed availability. However, the number of ICU beds per inhabitant in our study did not seem to be associated with admissions of

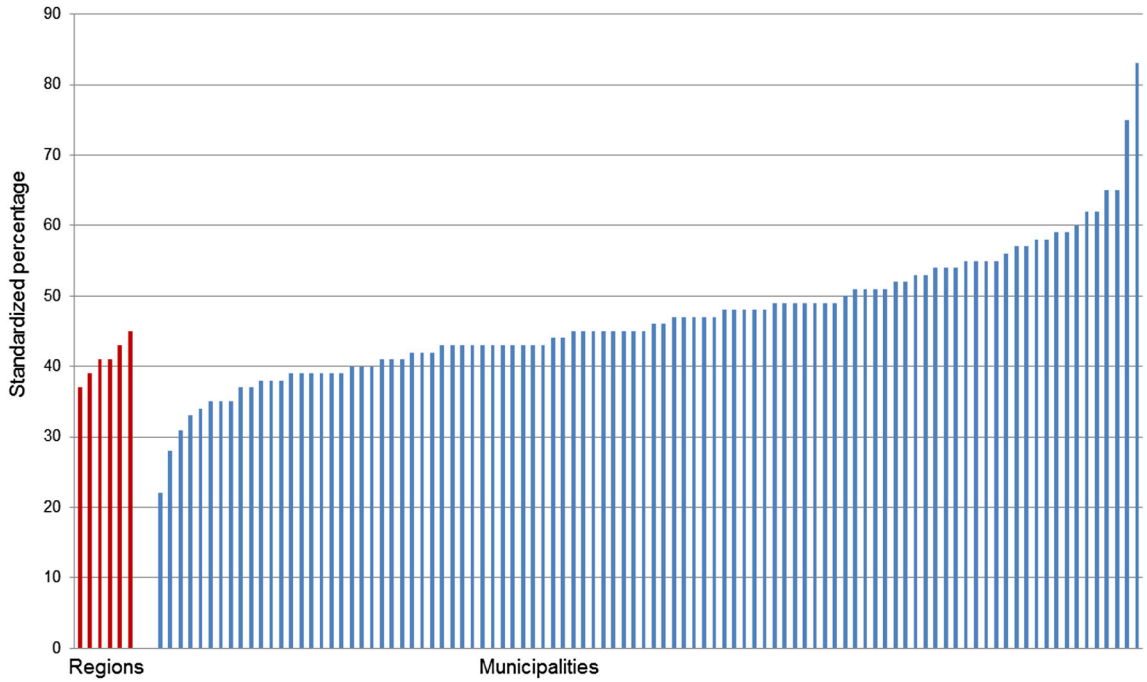

Fig. 2 Standardized percentages of ICU admissions treated with mechanical ventilation for the 5-year period 2008–2012

patients to ICUs since the highest numbers of ICU beds per inhabitant were found in Central Denmark Region and Capital Region which did not correspond to the relatively low number of ICU patients per 1000 person-years found particularly in the Capital Region. This pattern may be due to the fact that some highly specialized treatments including heart and lung transplantations, liver transplantations, advanced treatments of hematological cancers, and veno-venous extracorporeal membrane oxygenation are centered at hospitals and ICUs in these two regions, which may require a higher number of ICU beds than in other regions.

Only very few hospitals have step-down units, and there are limited options for close observation of patients outside the ICU at small hospitals. Therefore ICUs are often used for patients who do not require aggressive life-sustaining interventions but only close monitoring. This may partly explain why some geographical areas in our study had many ICU patients, including some patients not receiving any of the organ supportive interventions. However, it is unlikely to be the only explanation since we did not identify regions or municipalities with a combination of a high number of ICU patients per 1000 person-years together with low use of mechanical ventilation. This would otherwise have supported the hypothesis that the high number of ICU patients in some geographical areas was explained by admission of less severely ill patients. However, we identified the highest 30-day mortality in the Capital Region together with the lowest number of ICU patients and, additionally, the North Denmark Region had one of the lowest 30-day mortalities but the highest number of ICU patients. This could indicate case-mix differences of ICU patients, since patients who might have been admitted to an ICU in one region may be treated in a regular ward in other regions.

Furthermore, general morbidity patterns, e.g., of chronic diseases, may differ across the country. For instance, the age-standardized incidence of heart failure varies substantially among the Danish regions [19]. However, our results on comorbidity only showed limited regional differences among patients admitted to an ICU (Table 1).

Socioeconomic conditions may also influence some of the geographical variation since low socioeconomic status may be associated with poor health and chronic illnesses and thereby more ICU admissions. However, regarding average yearly income, an overview from Statistics Denmark [9] did not show any correlations between the number of ICU patients and the average yearly income.

On almost every smaller island we found more ICU patients per 1000 person-years than on the mainland. It is possible that these patients are more severely ill before they are transferred to the mainland and therefore end up being admitted to an ICU. Additionally, there might be some statistical uncertainty since populations on these islands are small.

This issue might also be the case when comparing municipalities since at least some of the variation may be explained by statistical imprecision due to fewer observations.

Concerning differences in registration and triage criteria for admission of an ICU patient, the triage criteria

for being admitted to an ICU may rely on clinical judgment rather than objective criteria. This is a possible mechanism by which some hospitals have higher or lower numbers of ICU patients per 1000 person-years than others—decisions may be arbitrary and vary depending on the ICU physician and the capacity [6, 20].

The main strengths of our study include its nationwide population-based design within the setting of a homogeneous healthcare system. Results were based on data on the number of ICU patients and type of therapy from highly validated, almost complete registries although the validations of the NRP, and thereby indirectly DID, were made on relatively small sample sizes and within only two of the Danish regions [13, 14]. In addition, we found low proportions of patients treated with non-invasive mechanical ventilation in some municipalities. We therefore cannot rule out that an incomplete registration of non-invasive ventilation may have influenced our results, but without this being systematic.

In the DID only few patients were not registered (estimated completeness is 95 %) [12], which indicates a low risk of selection bias.

However, in the calculations of LOS we assumed that LOS was similar for registered and non-registered patients although discharge date and time have separate codes implemented in 2009 and are therefore not complete throughout the study period.

Information concerning patients' residence and admission to an ICU were obtained from the NRP and DID, respectively. These data are registered prospectively without knowledge about the various outcomes. Of note, admissions were analyzed according to the patient's residency and not according to location of the ICU. Any bias from patients being transferred from regional hospitals to more specialized care at university hospitals is therefore unlikely.

There may be confounding from unmeasured factors and residual confounding. We did not have data on chronic diseases and lifestyle-associated conditions in the general population and could therefore not include this in the analysis of ICU patients. Even in the analysis of interventions among ICU patients, residual confounding from severity of comorbidity may influence our findings. Furthermore, data on Simplified Acute Physiology Score II (SAPS II) were incompletely registered in the study period and therefore not included in the analyses of ICU interventions. We also lacked data on lifestyle factors, but this may at least partly be accounted for by including lifestyle-associated comorbid conditions in the CCI.

Conclusion

There was only minimal geographical variation in the use of intensive care admissions and interventions at the regional level in Denmark, but more pronounced variation at the municipality level. These findings might partly reflect underlying geographical differences in disease patterns.

Compliance with ethical standards

Conflicts of interest The authors declare that they have no conflict of interest.

Ethical considerations The study was approved by the Danish Data Protection Agency (record number 2009-41-3987). According to Danish law, informed consent was not required.

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