Utilisation and time to performance of diagnostic imaging in patients admitted to Danish emergency departments: a nationwide register-based study from 2007 to 2017

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ABSTRACT

Objectives To describe the development of diagnostic imaging utilisation in Denmark from 2007 to 2017, coinciding with a major national reform of the emergency healthcare system.

Design Nationwide descriptive register-based study.

Setting All public hospitals in Denmark.

Participants All unplanned hospital contacts ≥18 years old at somatic hospitals in Denmark from 1 January 2007 to 31 December 2017.

Primary and secondary outcome measures The primary outcome measure was the probability of having CT, X-ray, MRI or ultrasound performed during hospitalisation in 2017 compared with 2007. The secondary outcome measure was receiving diagnostic imaging within 4 hours of hospitalisation.

Results The probability of having a radiological examination during unplanned hospital admission increased from 2007 to 2017 (CT: 3.5%–10.3%; MRI: 0.2%–0.8%; ultrasound: 2.3%–4.5%; X-ray: 23.8%–26.8%). For CT scan, the adjusted OR was 3.09 (95% CI: 2.73, 3.51); for MRI, the adjusted OR was 3.39 (95% CI: 1.87, 6.12) and for ultrasound, the adjusted OR was 1.93 (95% CI: 1.56, 2.38). The likelihood of having the examination within the first 4 hours in the hospital increased from 2007 to 2017. For X-ray, the adjusted OR was 1.39 (95% CI: 1.07, 1.76); for CT scan, the adjusted OR was 1.35 (95% CI: 1.16, 1.59); for MRI, the adjusted OR was 1.34 (95% CI: 1.09, 1.66) and for ultrasound, the adjusted OR was 1.38 (95% CI: 1.16, 1.64).

Conclusion This nationwide study describes the development of diagnostic imaging utilisation in Denmark from 2007 to 2017. The probability of receiving radiological examinations during unplanned hospitalisation increased over this period, and the time from hospital contact to performance decreased. This supports the notion that enhancement in radiological equipment will also lead to more frequent and faster utilisation.

INTRODUCTION

The global medical equipment market has been growing over the years and is estimated to continue to grow by 5.8% annually until 2028.1 Diagnostic imaging, which in this study is understood as CT, MRI, X-ray and ultrasound, is used to enhance the diagnostic process and is employed widely among different medical specialties. An advantage of using diagnostic imaging is avoiding more invasive measures.2 A study from 2013 investigated mortality among patients with high-risk emergency general surgery diagnoses and found that higher utilisation of CT scans reduced mortality.3 They also found that low-mortality hospitals had significantly higher utilisation of ultrasounds per bed per year.3

Hospitals in Denmark have been under extensive reconfiguration since the Danish Health Authority in 2007 published a report containing 24 recommendations to enhance acute care. One recommendation was to centralise hospitals and merge the units. The idea was that patients could be admitted through a single department at which diagnostic radiology should be available and a diagnostic radiology specialist available at all hours.4 Studies investigating unplanned hospital contacts during the reconfiguration have shown a general decrease in hospital length of stay and mortality and an increase in readmission rates.5,6 One aim of centralising
hospitals was to make specialised equipment such as X-ray, CT and ultrasound more accessible. We hypothesise that easier access to radiological equipment has enhanced the utilisation of diagnostic imaging and decreased the time from hospital contact to the performance of the imaging. Thus, this study aims to describe the development of utilisation and time to performance of diagnostic imaging in Denmark from 2007 to 2017.

**METHOD**

**Study design and population**

This was a nationwide register-based descriptive study, including all unplanned contacts ≥18 years old to somatic public hospitals in Denmark from 1 January 2007 to 31 December 2017. Planned admissions, admissions directly to a surgical or medical ward, psychiatric admissions and admissions in connection to labour were excluded.

**Setting**

Public hospitals in Denmark are tax funded, and no user fee is required when hospitalised or when in need of diagnostic imaging. Denmark is divided into five healthcare regions responsible for managing, planning and funding the hospitals within their geographical areas. In 2007, around 40 Danish somatic hospitals had one or several emergency departments, which should be reduced to 21 by 2025, each with one emergency department receiving almost all unplanned contacts.

**Data sources**

Data were extracted from the Danish National Patient Register, which contains data about patients who have
been in contact with Danish hospitals, including information on which hospital, time of admission, time of discharge, and diagnostic and procedural codes. The data were linked with the Danish Civil Registration System, which contains demographic information on all Danish citizens.

**Patient and public involvement**

This study was conducted without patient or public involvement.

**Outcome variables**

The primary outcome of interest was the probability of receiving diagnostic imaging during an unplanned hospitalisation. Our secondary outcome was the probability of receiving diagnostic imaging within the first 4 hours of hospital contact. The demarcation of 4 hours was chosen because several emergency departments have set the goal of establishing a plan for the patient within 4 hours, including an assessment of radiological images and assessing if more diagnostic procedures are relevant.

**Statistics**

Patient characteristics are presented in absolute and relative numbers. To examine the change in diagnostic imaging utilisation and whether it was performed within the first 4 hours of admission, we present raw numbers by year and adjusted ORs using logistic regressions. We adjusted for sex, age, comorbidity, educational level, yearly income, ethnicity and marital status. The regression analyses used clustered robust SE to account for within-hospital dependency. All data management and analyses were processed using Stata software, V.16.1.

**RESULTS**

In total, 12,591,210 acute contacts were included. Men accounted for 51.0% of contacts, 18.7% were 18–29 years old, 58.8% had a low Charlson’s Comorbidity Score, 74.4% had a medium educational level, 42.2% had a yearly income below €26,000 and 89.6% were of Danish origin (table 1). In 2017, the contacts receiving any of the four types of diagnostic imaging were older, more comorbid and had a higher yearly income, compared with 2007. They were also less likely to be of male sex, Danish origin or married (table 1). X-rays were mostly used, followed by CT scans, ultrasounds and MRIs. The distribution in the use of diagnostic imaging could indicate a skewness in some cases—for example, in favour

![Figure 1](http://bmjopen.bmj.com/)

(A) Number of diagnostic imaging performances per 10,000 contacts. (B) OR of receiving diagnostic imaging. (C) Mean time to the first diagnostic imaging. (D) OR of receiving diagnostic imaging within the first 4 hours of admission.
of highly educated patients or those with a high income receiving MRI (online supplemental table 1).

X-ray

The percentage of patients receiving an X-ray during hospital admission changed from 23.8% in 2007 to 26.8% in 2017 (figure 1A and table 2); however, the odds of receiving an X-ray did not change from 2007 to 2017 (2017: OR 1.15; 95% CI: 0.99, 1.33) (figure 1B and table 2). The mean time from arrival to performance of an X-ray within 4 hours increased from 81.3% in 2007 to 83.6% in 2017 (adjusted OR 1.30; 95% CI: 1.07, 1.56) (figure 1D and table 3).

CT scan

The percentage of patients receiving a CT scan during hospital admission changed from 3.5% in 2007 to 10.3% in 2017 (figure 1A and table 2). The odds of CT scan performance during hospitalisation increased year by year during the study period. The adjusted OR in 2017 was 3.09 (95% CI: 2.73, 3.51) compared with 2007 (figure 1B and table 2). The mean time from arrival to performance of a CT scan was 3.6 hours in 2007, decreasing to 3.2 hours in 2017 (figure 1C and table 3). The percentage of patients receiving a CT scan within 4 hours increased from 65.3% in 2007 to 71.2% in 2017 (adjusted OR 1.35; 95% CI: 1.16, 1.59) (figure 1D and table 3).

MRI

The percentage of patients receiving an MRI during hospitalisation was 0.2% in 2007 and 0.8% in 2017 (figure 1A and table 2). The adjusted OR of receiving MRI during hospitalisation was 3.39 (95% CI: 1.87, 6.12) in 2017 compared with 2007 (figure 1B and table 2). The mean time from arrival to performance of an MRI decreased from 4.3 hours in 2007 to 3.7 hours in 2017 (figure 1C and table 3). The percentage of patients receiving MRI within 4 hours of admission increased from 53.6% in 2007 to 62.2% in 2017 (adjusted OR 1.34; 95% CI: 1.09, 1.66) (figure 1D and table 3).

<table>
<thead>
<tr>
<th>Year</th>
<th>Observations N</th>
<th>X-ray</th>
<th>OR (95% CI)</th>
<th>CT scan</th>
<th>OR (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>N (%)</td>
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<td>N (%)</td>
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<tr>
<td>2007</td>
<td>1084038</td>
<td>258048 (23.8)</td>
<td>1.00 (reference)</td>
<td>37850 (3.5)</td>
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</tr>
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<td>2008</td>
<td>1090440</td>
<td>259445 (23.8)</td>
<td>1.00 (0.98, 1.02)</td>
<td>43828 (4)</td>
<td>1.15 (1.12, 1.19)</td>
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<td>2009</td>
<td>1122166</td>
<td>261927 (23.3)</td>
<td>0.97 (0.94, 1.01)</td>
<td>50126 (4.5)</td>
<td>1.28 (1.22, 1.35)</td>
</tr>
<tr>
<td>2010</td>
<td>1119744</td>
<td>274372 (24.5)</td>
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<td>57615 (5.1)</td>
<td>1.48 (1.39, 1.58)</td>
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<td>271848 (24.3)</td>
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<td>65167 (5.8)</td>
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<tr>
<td>2012</td>
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<td>72733 (6.7)</td>
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<td>2013</td>
<td>1083373</td>
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<td>79570 (7.3)</td>
<td>2.13 (1.86, 2.44)</td>
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<td>2014</td>
<td>1217421</td>
<td>278492 (22.9)</td>
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<td>2.21 (1.96, 2.49)</td>
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<td>2015</td>
<td>1212340</td>
<td>288285 (23.8)</td>
<td>0.98 (0.85, 1.13)</td>
<td>100301 (8.3)</td>
<td>2.44 (2.15, 2.76)</td>
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<td>2016</td>
<td>1220618</td>
<td>305618 (25)</td>
<td>1.05 (0.90, 1.22)</td>
<td>109594 (9)</td>
<td>2.67 (2.33, 3.06)</td>
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<tr>
<td>2017</td>
<td>1230787</td>
<td>329295 (26.8)</td>
<td>1.15 (0.99, 1.33)</td>
<td>127273 (10.3)</td>
<td>3.09 (2.73, 3.51)</td>
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</table>

<table>
<thead>
<tr>
<th>Year</th>
<th>Observations N</th>
<th>MRI scan</th>
<th>OR (95% CI)</th>
<th>Ultrasound</th>
<th>OR (95% CI)</th>
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<td>N (%)</td>
<td></td>
<td>N (%)</td>
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<td>35645 (3.3)</td>
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<td>45468 (3.7)</td>
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<td>2016</td>
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<td>3.01 (1.57, 5.74)</td>
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<td>9461 (0.8)</td>
<td>3.39 (1.87, 6.12)</td>
<td>54928 (4.5)</td>
<td>1.93 (1.56, 2.38)</td>
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</tbody>
</table>

*Adjusted for sex, age, comorbidity, educational level, yearly income, ethnicity and marital status.*
The percentage of patients receiving an ultrasound during hospital admission changed from 2.3% in 2007 to 4.5% in 2017 (figure 1A and table 2). The use of ultrasound increased from 2007 and onwards, reflected in an adjusted OR of 1.95 (95% CI: 1.56, 2.38) in 2017 (figure 1B and table 2). The mean time from arrival to performance of an ultrasound decreased from 4.4 hours in 2007 to 3.7 hours in 2017 (figure 1C and table 3). The percentage of patients who received an ultrasound within 4 hours of admission increased from 54.2% in 2007 to 62% in 2017 (adjusted OR 1.38; 95% CI: 1.16, 1.64) (figure 1D and table 3).

**DISCUSSION**

The odds of receiving a CT scan, MRI or ultrasound during hospitalisation increased over the study period. The odds of receiving an X-ray during hospitalisation did not change. During the study period, the mean time from admission to performance of diagnostic imaging decreased, and the odds of receiving all four types of diagnostic imaging within the first 4 hours of admission increased. The patients receiving diagnostic imaging during hospital admission in 2017 were older and more comorbid compared with the patients in 2007. This could possibly contribute to the increase in usage of diagnostic imaging, as these patients often present with more complex symptoms and thus might more often require radiological examinations.

**Comparison with previous studies**

To our knowledge, this is the first study to examine diagnostic imaging utilisation during hospital reconfigurations. The increased utilisation of diagnostic imaging could contribute to the observed simultaneous decrease in the length of stay in Danish emergency care. One reason could be that increased and faster use of diagnostic imaging contributed to the observed simultaneous decrease in the length of stay in Danish emergency care.5 One reason could be that increased and faster use of diagnostic imaging contributed to the observed simultaneous decrease in the length of stay in Danish emergency care.5 One reason could be that increased and faster use of diagnostic imaging contributed to the observed simultaneous decrease in the length of stay in Danish emergency care.5 One reason could be that increased and faster use of diagnostic imaging contributed to the observed simultaneous decrease in the length of stay in Danish emergency care.5 One reason could be that increased and faster use of diagnostic imaging contributed to the observed simultaneous decrease in the length of stay in Danish emergency care.5 One reason could be that increased and faster use of diagnostic imaging contributed to the observed simultaneous decrease in the length of stay in Danish emergency care.5 One reason could be that increased and faster use of diagnostic imaging contributed to the observed simultaneous decrease in the length of stay in Danish emergency care.5 One reason could be that increased and faster use of diagnostic imaging contributed to the observed simultaneous decrease in the length of stay in Danish emergency care.5 One reason could be that increased and faster use of diagnostic imaging contributed to the observed simultaneous decrease in the length of stay in Danish emergency care.5 One reason could be that increased and faster use of diagnostic imaging contributed to the observed simultaneous decrease in the length of stay in Danish emergency care.5 One reason could be that increased and faster use of diagnostic imaging contributed to the observed simultaneous decrease in the length of stay in Danish emergency care.5 One reason could be that increased and faster use of diagnostic imaging contributed to the observed simultaneous decrease in the length of stay in Danish emergency care.5 One reason could be that increased and faster use of diagnostic imaging contributed to the observed simultaneous decrease in the length of stay in Danish emergency care.5 One reason could be that increased and faster use of diagnostic imaging contributed to the observed simultaneous decrease in the length of stay in Danish emergency care.5 One reason could be that increased and faster use of diagnostic imaging contributed to the observed simultaneous decrease in the length of stay in Danish emergency care.5 One reason could be that increased and faster use of diagnostic imaging contributed to the observed simultaneous decrease in the length of stay in Danish emergency care.5 One reason could be that increased and faster use of diagnostic imaging contributed to the observed simultaneous decrease in the length of stay in Danish emergency care.5 One reason could be that increased and faster use of diagnostic imaging contributed to the observed simultaneous decrease in the length of stay in Danish emergency care.5 One reason could be that increased and faster use of diagnostic imaging contributed to the observed simultaneous decrease in the length of stay in Danish emergency care.5 One reason could be that increased and faster use of diagnostic imaging contributed to the observed simultaneous decrease in the length of stay in Danish emergency care.5 One reason could be that increased and faster use of diagnostic imaging contributed to the observed simultaneous decrease in the length of stay in Danish emergency care.5 One reason could be that increased and faster use of diagnostic imaging contributed to the observed simultaneous decrease in the length of stay in Danish emergency care.5
imaging could lead to quicker and more accurate diagnoses, leading to faster initiation of treatment and, thus, a shortened length of hospital stay. However, this chain of events is speculative and not empirically confirmed. Previous studies did not find any association between the reconfiguration of emergency departments and overall mortality. However, a decreasing mortality trend was observed, and an association within specific diagnoses, including aortic aneurysms, strokes, myocardial infarctions and major traumas, was found. The increased use of diagnostic imaging at an earlier time in the process may contribute to this development. A Canadian study supports this statement by showing a decrease in mortality associated with increased acquisition of CT and magnetic resonance scanners. We also found that patients with higher education and income levels are more likely to receive MRIs during their hospital admission. These results correspond with two Canadian studies. One found increased usage of diagnostic imaging in general in patients with a higher socioeconomic status; the other found significantly higher utilisation of MRI in patients with higher socioeconomic status. As in Denmark, hospital services in Canada are publicly funded.

Strengths and limitations
A strength of the study is that data from the Danish National Patient Register are on patients nationwide, and we included data from all public hospitals in Denmark. A further strength is the use of the Danish personal identification number to link each patient between registries, which made it possible to adjust the analysis for demographic development. The study would have been further strengthened if we had had the specific numbers of and acquisition dates for the new radiological equipment. However, nationwide reports show new equipment purchases and an increased presence of qualified personnel to carry out examinations. Therefore, we are confident that changes have been made according to the goal set by the Danish Health Authority to establish easier access to radiological equipment in emergency departments. However, we cannot distinguish whether the effect is due to better access to equipment or more presence of qualified personnel. This study evaluates only the overall development. We are missing identification of the number of acutely admitted patients due to discoveries in planned diagnostic imaging. These patients received a radiological examination performed immediately before admission; this examination is not included in our data. Finally, this nationwide analysis should be interpreted cautiously at a hospital level.

Implications
The Danish Ministry of Health anticipates an increase in older patients, and thus an increase in the utilisation of diagnostic imaging, and will therefore improve the medical equipment available at Danish hospitals. The results of this study support the notion that an enhancement in radiological equipment will also lead to more frequent and faster utilisation. If health systems want quick access to diagnostic imaging, funds must be continuously allocated, as it must be expected that new and better equipment will be available in the future. This is in line with the Danish Ministry of Health, which has estimated diagnostic imaging to increase by 40% by 2025 compared with 2018, and thus, a part of €114 million has been allocated to the purchase of medical equipment in 2022. However, faster and higher utilisation of diagnostic imaging is not solely considered beneficial. An opinion by consultant radiologist, Maskell, is the increased utilisation of diagnostic imaging can be ascribed to reduced tolerance of uncertainty and as a result, radiological examinations are also performed on patients, who might not benefit from them.

CONCLUSION
This nationwide study describes the development of diagnostic imaging utilisation in Denmark from 2007 to 2017. The probability of receiving radiological examinations during unplanned hospital admission increased, and the time from admission to performance of diagnostic imaging decreased over this period. The results suggest that investments in radiological equipment and more presence of qualified personnel are linked to an increased rate of diagnostic imaging.

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Competing interests None declared.

Patient and public involvement Patients and/or the public were not involved in the design, or conduct, or reporting, or dissemination plans of this research.

Patient consent for publication Not required.

Ethics approval When conducting register-based studies in Denmark, there is no obligation to notify the ethical committees. No included patients are identifiable, as data are pseudonymised. The Danish Data Protection Agency has approved the project (file no. 17/18411).
REFERENCES


Provenance and peer review Not commissioned; externally peer reviewed.

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