■ TRAUMA

High volumes of recent surgical admissions, time to surgery, and 60-day mortality

A COHORT STUDY OF 60,000 NORWEGIAN HIP FRACTURE PATIENTS

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Aims
Few studies have investigated potential consequences of strained surgical resources. The aim of this cohort study was to assess whether a high proportion of concurrent acute surgical admissions, tying up hospital surgical capacity, may lead to delayed surgery and affect mortality for hip fracture patients.

Methods
This study investigated time to surgery and 60-day post-admission death of patients 70 years and older admitted for acute hip fracture surgery in Norway between 2008 and 2016. The proportion of hospital capacity being occupied by newly admitted surgical patients was used as the exposure. Hip fracture patients admitted during periods of high proportion of recent admissions were compared with hip fracture patients admitted at the same hospital during the same month, on similar weekdays, and times of the day with fewer admissions.

Results
Among 60,072 patients, mean age was 84.6 years (SD 6.8), 78% were females, and median time to surgery was 20 hours (IQR 11 to 29). Overall, 14% (8,464) were dead 60 days after admission. A high (75th percentile) proportion of recent surgical admission compared to a low (25th percentile) proportion resulted in 20% longer time to surgery (95% confidence interval (CI) 16 to 25) and 20% higher 60-day mortality (hazard ratio 1.2, 95% CI 1.1 to 1.4).

Conclusion
A high volume of recently admitted acute surgical patients, indicating probable competition for surgical resources, was associated with delayed surgery and increased 60-day mortality.

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Introduction
Early surgery for hip fracture patients is a key indicator of care quality in many healthcare systems.[1-3] To reduce complications and mortality, it is generally recommended that surgery should be performed as early as possible.[4-11] Higher mortality due to delay in surgery may reflect effects of delayed surgery, but could also be driven by unmeasured factors leading to residual confounding, since patients with complex medical comorbidities may require medical optimization. These patients may thus be predisposed to delayed surgery and complications.

Restricted availability of operating rooms or other resources may result in delayed surgery for hip fracture patients,[12-14] and could also cause other adverse effects . Few studies have addressed how strained hospital resources may affect treatment and outcomes for hip fracture patients, although there is some evidence that differences in hospital organization, e.g. degree of specialization and geographical location, may be associated with time to surgery and postoperative mortality.[15-17]

Hospital organization and patient populations may differ between hospitals. We therefore designed a study that compared patients within hospitals. By using available information on admission and discharge of all acute surgical patients within each hospital, we could identify hospital workload and resulting strain in resources. To account for differences in patient severity and hospital organization over time,[18] we compared patients who were admitted during similar weekdays and times of the day, and within the same

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month. For instance, patients admitted on a Monday night were only compared to other patients also admitted on Monday nights during the same month at the same hospital. Using this approach, we estimated the effect of hospital workload on concurrent surgical patients with regard to time to surgery and 60-day mortality among Norwegian hip fracture patients.

Methods

Study cohort. In Norway, four regional health authorities are responsible for providing secondary care services. Within each health authority, acute hip fracture surgery is provided by local hospitals within separate catchment areas.[19] Four of these hospitals are both level 1 trauma centres and university hospitals. We used data from the Norwegian Patient Registry to acquire information about the nationwide cohort of 60,072 hip fracture patients with 65,097 admissions from 1 January 2008 to 31 December 2016. All Norwegian hospital trusts are required to submit information about their clinical activity to the national patient registry.[20] Time of surgery for hip fracture patients was available for most patients from 2010. Date of death was collected from the Norwegian Cause of Death Registry. Information on contacts with regular general practitioners (GPs) was obtained from the Norwegian Health Economics Administration database (Helfo).

Patients admitted with a hip fracture were identified through a combination of International Classification of Diseases of the World Health Organization (ICD)-10 codes[21] and the Nordic Medico-Statistical Committee (NOMESCO) Classification of Surgical Procedures codes.[22] We included acute patients with ICD-10 codes S72.0x, S72.1x, or S72.2x (fracture of proximal femur) as primary diagnosis and one or more NOMESCO codes, NFBxy (x = 0 to 9, y = 0 to 2, primary prosthetic arthroplasty of hip joint), or NFJxy (x = 0 to 9, y = 0 to 2, fracture surgery of proximal femur) during their hospitalization. This definition has previously shown high accuracy in identifying hospitalizations for hip fractures while excluding stays due to rehabilitation.[23] We also included hip fracture patients without the procedure codes who died in hospital, because they could have died before a required operation. For patients who were hospitalized more than once within 30 days, we only included the first stay, and thus we avoided more than one entry for the same fracture. Admissions to hospitals with a mean of less than 50 admissions for hip fracture per year were excluded, leaving 45 hospitals in the analysis. We included patients who were 70 years of age or older at admission.

Measures. The main outcomes were time to surgery and death within 60 days after admission. Secondary outcomes were 30- and 90-day mortality, length of postoperative stay, and hospital stays up to 60 days after admission, and the number of GP visits during the subsequent 60 days.

The main exposure was the number of concurrent acute surgical patients admitted up to 48 hours prior to the index patient (counted from the end of six-hour intervals (6:00, 12:00, 18:00, and 24:00). This number was divided by the monthly hospital-specific mean occupancy of acute surgical patients at noon. The exposure thus represented the proportion of the hospital capacity being occupied by recently admitted patients. We only counted admissions of acute patients since these admissions are out of the hospitals' control. These were patients who underwent a surgical procedure during the study period, regardless of the diagnosis. Time of surgery was not available for these patients, but a separate analysis showed that patients admitted earlier than 48 hours prior did not substantially impact time to surgery for hip fracture patients (for analysis, code and figure, see online Supplementary Material Figure a and additional text in the online Supplementary Material), suggesting that these patients did not compete for surgical resources. See Table I for details on the inclusion and exclusion criteria for the cohort of hip fracture patients, and potentially competing surgical patients.

Table I. Assembly of the study cohort and potentially competing surgical patients.

Study cohort	n
Inclusion criteria	
Acute admission between 2008 and 2016 with primary ICD-10 diagnosis S72.0x, S72.1x, or S72.2x	83,767
Exclusion criteria	
Admitted at a hospital with a mean of less than 50 admissisons for hip fracture per year	2,167
Discharged alive without surgery (NOMESCO codes NFBxy or NFJxy, x = 0to 9, y = 0,1,2)	4,529
Admitted with hip fracture < 30 days earlier	272
Patients aged < 70 years	11,702
Index hip fracture admissions	65,097
Potentially competing patients	
Inclusion criteria	
Acute admissions from 2008 to 2016	5,098,059
Exclusion criteria	
No surgical procedure during hospitalization	4,468,485
Admitted at hospital with a mean of less than 50 hip fractures per year	3,615
Potentially competing patients	625,959

ICD, International Classification of Diseases of the World Health Organization.

Statistical analysis. Confounding may be a major source of bias in observational studies. One way to control for confounding is to analyze within clusters of individuals, where the individuals share a large set of potential confounders within each cluster. This effectively controls for all shared or constant confounding factors. Such designs have been extensively used in family studies comparing differentially exposed siblings.[24]

We identified clusters of patients admitted at the same hospital, during the same month, on similar weekdays (holidays were coded as Sundays) and times of day (in similar six-hour partitions of the day). Mortality was analyzed as time-to-event using stratified Cox regression, with time from admission as the time scale. Patients were followed for up to 60 days or until the end of 2016. We defined strata according to the clustering variable, the estimation was only based on within-stratum variability, and these analyses thus adjusted for confounders that were constant within each stratum during follow-up (e.g. hospital-specific time-confounding factors). For continuous outcomes, like time to surgery, we used fixed effects linear regression, and for dichotomous outcomes conditional logistic regression. To assess a possible non-linear association, we used natural cubic splines with four nodes placed according to recommendations by Harrell.[20] The resulting spline curves were plotted using estimated difference in outcome, relative to the median in the data material, applying the xblc command in Stata (StataCorp, College Station, Texas, USA). Summary statistics were reported as the difference between the 75th and 25th percentiles of the proportion of hospital capacity being occupied by recently admitted surgical patients. All analyses of time to surgery and length of stay were done using log-transformed time. To improve precision, analyses were adjusted for differences in patient characteristics, including age (with a quadratic term), sex, intracapsular fracture (ICD 10-code S72.0x), any previous admissions during the last 60 days, and visits to a GP during the last 60 days.

The analyses were performed with Stata version 15.1 and R version 1.1.463 (R Foundation for Statistical Computing, Vienna, Austria). We present the code for the analyses in the online Supplementary Material.

Assumptions and additional analyses. Given our model, we assumed that arrivals of surgical patients were likely to be largely random, minimizing the potential for confounding. To test this, we calculated the association with known indicators of the hip fracture patients' condition: age, sex, intracapsular fracture, previous hospital admissions during the last 60 days, the number of visits to a GP 60 days prior to admission to hospital, and Charlson Comorbidity Index (CCI)[25] calculated from inpatient treatment occurring within 365 days preceding the index admission.

We performed separate analyses of time to surgery where patients undergoing any orthopaedic procedure and procedures related to the digestive system were left out of the exposure (chapters N and J of the NOMESCO classification).[22]

To assess whether the results could be affected by hospital-wide trends, for example caused by limited hospital resources affecting all patients, we estimated the association between the proportion of recently admitted surgical patients and mortality for patients admitted for pneumonia. We also tested whether a high volume of recently admitted surgical patients affected mortality in patients undergoing acute surgery for cardiovascular diseases (ICD 10 chapter 9) to assess whether a patient group which may be presumed to be prioritized was affected by potentially competing patients.

The analyses were performed separately for patients with intracapsular and extracapsular fracture, patients admitted during regular working hours or not, patients admitted on workdays or not, patients admitted during winter months or not, and patients admitted before and after 2014. We also performed the analyses separately for patients admitted at one of the four level 1 trauma centres/university hospitals or not.

Results

Among the 65,097 admissions that met the inclusion criteria, mean (SD) age was 84.6 years (6.8) and 78% were female (see Table II). Hip fracture patients aged 70 years and older made up 8% of all emergency surgery in Norway during the study period. Time to surgery was not reliably registered at the beginning of the study period. Between 2008 to 2009 only 270 (2%) of patients had time of surgery recorded, whereas that information was available for 6,052 (84%) of the patients in 2010. Therefore, all analyses of time to surgery were only done using admissions from the years 2010 to 2016.

Table II. Descriptive statistics on the study cohort.

Study cohort	n
Admissions for hip fracture, n (%)	60,097
Missing time to surgery, n (%)*	20,319 (34)
Baseline characteristics	
Mean age, yrs (SD)	84.6 (6.8)
Female sex, n (%)	46,783 (78)
Intracapsular fracture	38,788 (65)
CCI > 0, n (%)	20,878 (35)
Admitted in previous 60 days, n (%)	4,754 (8)
GP visit in previous 60 days, n (%)	51,629 (86)
Outcomes	
Dead 60 days after admission, n (%)	8,464 (14)
Median time to surgery, hrs (IQR)	20 (11 to 30)
Median postoperative LOS, days (IQR)	4.7 (2.9 to 7.2)
Median LOS within 60 days	6.6
GP visit in previous 60 days, n (%)	36,984 (62)

*Most admissions from 2008 to 2009 had missing time to surgery. 6,025 (12%) patients had missing data for time to surgery between 2010-2016.
CCI, Charlson Comorbidity Index; GP, general practitioner; IQR, interquartile range; LOS, length of stay.

Figure 1 shows the associations between the proportion of recently admitted surgical patients and time to surgery and 60-day mortality, relative to the median situation. The median proportion of recently admitted surgical patients was 0.32, (interquartile range (IQR) 0.25 and 0.41, respectively). Comparing the outcomes of recently admitted surgical patients between the higher and lower quartiles, time to surgery was 20% longer (95% confidence interval (CI) 16 to 25), which translates to four additional hours for a patient with the median time to surgery, and the hazard ratio for 60-day mortality was 1.2 (95% CI 1.1 to 1.4).

There was a similar increase in 30- and 90-day mortality (results not shown). Comparing the higher and lower quartiles of recently admitted surgical patients, time to surgery was 14% longer (95% CI 0 to 30) when excluding orthopaedic surgery and 18% longer (95% CI 6 to 33) when excluding procedures related to the digestive system (results not shown).

Table III shows the estimates of difference in patient characteristics and outcomes between the higher and lower quartiles of recently admitted surgical patients. There were little or no apparent differences in measured patient characteristics (age, sex, intracapsular fracture, CCI, admissions within the previous 60 days, GP visits within the previous 60 days) among hip fracture patients (see also Supplementary Material Figure e). Further, there were no apparent differences in secondary outcomes; length of postoperative stay, hospital stays up to 60 days after admission, and the number of GP visits during the subsequent 60 days. Spline curves for the secondary outcomes are shown in online Supplementary Material Figures b to d.

There was little evidence for any association with 60-day mortality for patients admitted for pneumonia (HR for IQR was 0.96, 95% CI 0.87 to 1.07), nor for acute surgical patients with cardiovascular diagnoses (HR 1.01, 95% CI 0.95 to 1.08; online Supplementary Material Figures f and g).

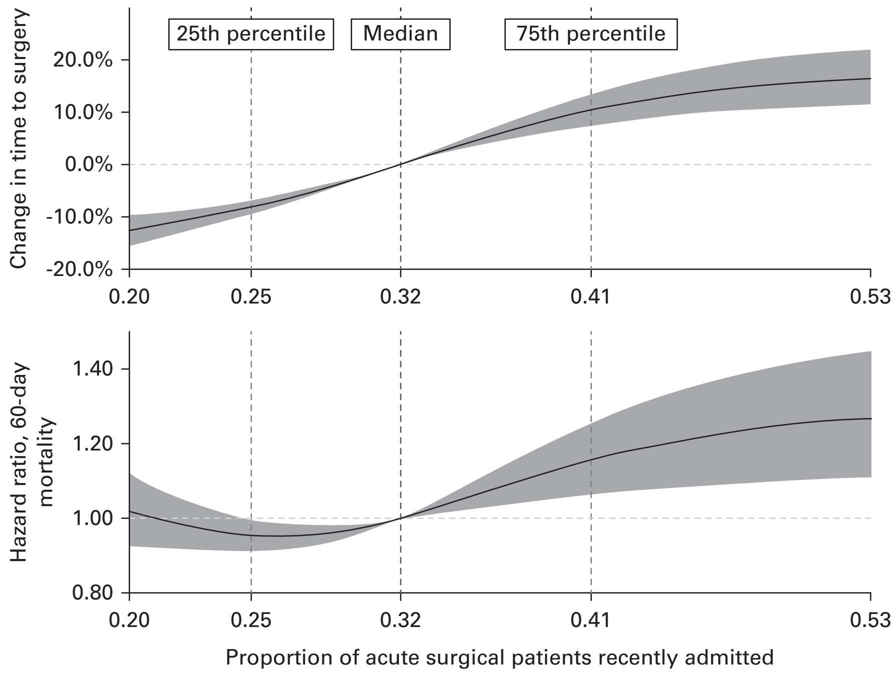

Fig. 1

Estimated difference in a) time to surgery (n = 44,508) and b) 60-day mortality (n = 65,097) as a function of the proportion of recently admitted surgical patients, relative to the median. The associations were calculated by comparing patients admitted at the same hospital, during the same month, on similar weekdays and times of day, and were adjusted for age with a quadratic term, sex, S72.0-diagnosis, previous admission, and previous GP visits. Median, 25th and 75th percentiles of the exposure are indicated with vertical, dashed lines.

Figure 2 shows the results of the subgroup analyses. All subgroups exhibited increased time to surgery and higher 60-day mortality with a higher proportion of surgical patients being recently admitted.

Discussion

Among 60,000 patients undergoing hip fracture surgery in Norway between 2008 and 2016, those who were admitted during periods of pressure on resources, due to concurrent high volumes of surgical admissions, had longer time to surgery and higher 60-day mortality. High- versus low-volume situations gave a mean delay in time to surgery of 20%, corresponding to four hours of additional waiting time for a typical patient, and 20% higher mortality.

The association between delayed surgery and mortality for hip fracture patients has received considerable interest,[4-9] but studies on the consequences of strained surgical resources are scarce. A scoping review had identified several patient and system factors associated with time to surgery.[17] There was no consensus about which clinical features represented appropriate delays, although longer time to surgery due to restricted resource availability was generally considered inappropriate. Most of the previous observational studies had small sample sizes and may have been influenced by unmeasured factors.

We found that surgery was delayed in hip fracture patients who were admitted during periods of high volumes of acute surgical admissions. This finding may indicate that hip fracture patients were not prioritized during periods of high activity. The association between high-volume recent acute surgical admissions and longer time to surgery was somewhat attenuated, but still evident after excluding orthopaedic surgery or procedures related to the digestive system from the exposure.

Furthermore, delayed surgery among hip fracture patients may have threatened their safety, as shown by their higher

Table III. Estimated difference in patient characteristics and outcomes between the 75th and 25th percentiles of the proportion of recently admitted surgical patients.

Recently admitted surgical patients	Change from 25th to 75th percentile of the exposure (95% CI)[1]	Effect measure
Missing time to surgery	1.06 (0.85 to 1.31)	OR
Baseline characteristics		
Mean age, yrs (SD)	-0.06 (-0.32 to 0.19)	Years
Female sex	0.94 (0.87 to 1.03)	OR
Intracapsular fracture	0.97 (0.90 to 1.05)	OR
CCI > 0	1.01 (0.90 to 1.14)	OR
Admitted in previous 60 days	0.96 (0.83 to 1.12)	OR
GP visit in previous 60 days	1.02 (0.92 to 1.12)	OR
Outcomes		
Dead 60 days after admission	1.21 (1.07 to 1.36)	HR
Time to surgery	20.2 (15.6 to 25.0)	%
Postoperative LOS	-1.5 (-5.9 to 3.1)	%
Median LOS within 60 days	0.8 (-21.0 to 28.6)	%
GP visit within 60 days	1.02 (0.94 to 1.12)	OR

All estimates are based on within stratum variability (hospital, year, month, day of the week and time of day) from separate models with adjustments as specified in Supplementary Material Figures b to e.
CCI, Charlson Comorbidity Index; CI, confidence interval; GP, general practitioner; HR, hazard ratio; OR, odds ratio.

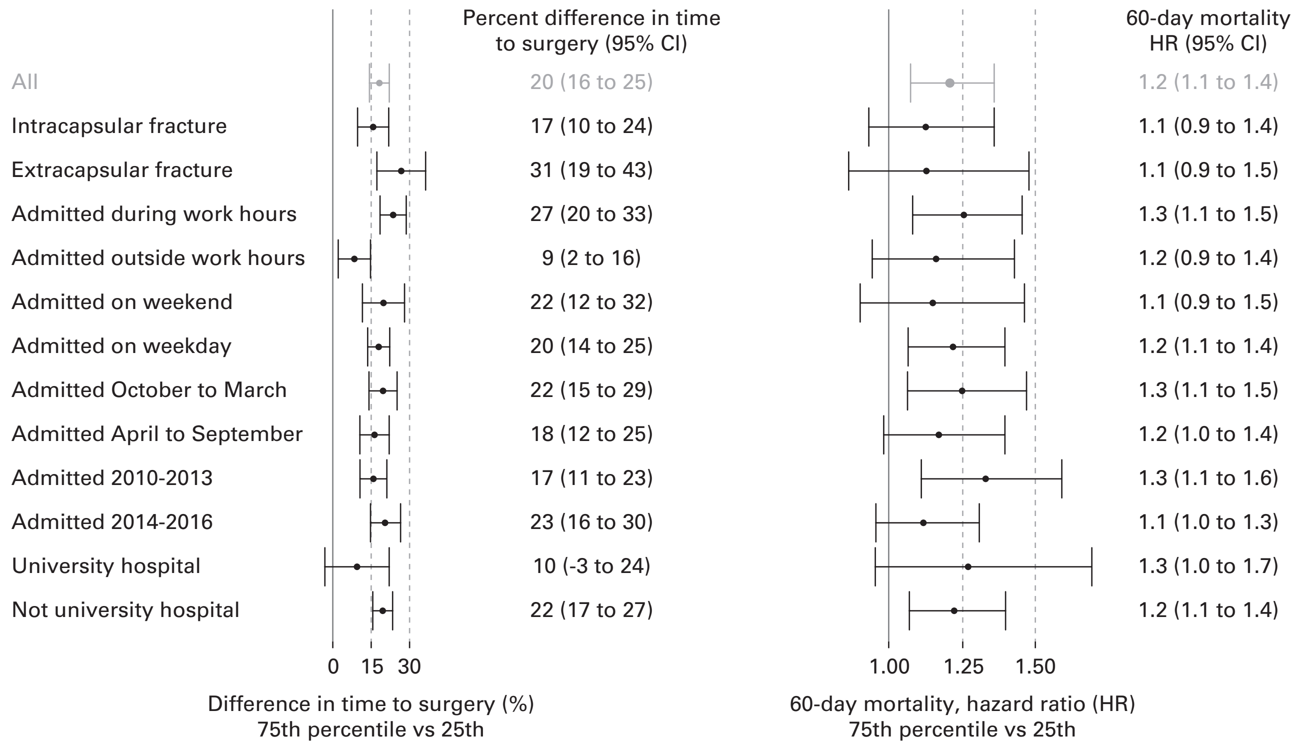

Fig. 2

Subgroup analyses of the estimated difference in time to surgery (left) and 60-day mortality (right) for hip fracture patients, including estimates of the difference between the higher and lower quartiles of recently admitted surgical patients. The associations were calculated by comparing patients admitted at the same hospital, during the same month, on similar weekdays and times of the day, and were adjusted for age with a quadratic term, sex, S72.0-diagnosis, previous admission, and previous general practitioner visits. CI, confidence interval; HR, hazard ratio.

60-day mortality during times of increased surgical admissions, thus risking competition for surgical resources. It is also possible that periods of high surgical admissions, resulting in admission wards full to capacity, may be associated with suboptimal postoperative care.[14,26–28] We found little evidence of any association between the proportion of the hospital capacity being occupied by recently admitted surgical patients and mortality among patients admitted for pneumonia, suggesting that our results were not due to a hospital-wide phenomenon that might have affected all patients. There was also no apparent association with mortality among cardiovascular patients admitted for surgery, which may be a highly prioritized patient group during situations of competition for finite surgical resources. In this context, hip fracture patients seem to represent a vulnerable group.

The large number of participants in this study provided relatively precise estimates of effects. We used information about primary diagnosis, and procedures and their timing; the quality of this information is regarded to be quite satisfactory.[29] Information on deaths from any cause during 60 days of follow-up, not limited to in-hospital deaths, was available for every patient from the Norwegian Cause of Death Registry.[30]

For the estimates to be valid, hip fracture patients admitted during periods of high-volume concurrent acute surgical admissions should have comparable comorbidities to patients admitted during low-volume admissions. We found no clear associations with measured indicators of the patients' condition, thus strengthening our assumption. Nevertheless, since this is an observational study, we cannot confidently rule out residual confounding that may have influenced our results.

Our study highlights the prioritization involved in planning acute surgery, and how a large but frail group of hip fracture patients may have been disadvantaged compared to other patient groups. Patient-centered hospital logistics has been proposed as a method for introducing more effective clinical pathways to alleviate prioritization conflicts.[31,32] Following this concept, creating separate pathways for acute surgical patients, such as hip fracture patients, could minimize delays due to organizational factors. This includes the allocation of specific operating rooms and medical teams.[33] One motivation for separate pathways for hip fracture patients is their large volume. In Norway, hip fracture patients older than 70 years constitute 8% of all acute surgery.

In summary, we found that hip fracture patients admitted at times of concurrent high-volume acute surgical admissions waited longer for surgery , and, compared to other hip fracture patients, their 60-day mortality was higher.

Take home message

- Using time of admission and discharge for all acute surgical patients in Norwegian hospitals over a nine-year period, we identified hospital-specific situations where hip fracture patients may have been exposed to pressure on surgical resources.
- Hip fracture patients admitted in periods with high surgical activity had longer time to surgery and increased 60 days mortality.
- Creating separate pathways for acute surgical patients, such as hip fracture patients, could help to minimize delays and avoid other potentially harmful situations.

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Supplementary material

An analysis of the association between time since arrival of a concurrent patient and time to surgery for hip fracture patients, and Stata code for computing this, as well as the indicator of surgical activity. Additional figures are also included showing secondary outcomes (length of post-operative stay and stays within 60 days; general practitioner visits), independence assumptions, and effect on 60-day mortality for patients with cardiovascular disease and pneumonia.

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F. Carlsen: Designed the study, Interpreted the data, Helped to write the final draft of the manuscript.
K. S. Anthun: Prepared the data material for analysis, Interpreted the data, Helped to write the final draft of the manuscript.
L. G. Johnsen: Interpreted the data, Helped to write the final draft of the manuscript.
L. J. Vatten: Interpreted the data, Helped to write the final draft of the manuscript.
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Data sharing:
The data of this study are publicly available, but restrictions apply to the availability. These data were used under license for the current study.

Ethical review statement:
The study was approved by the Regional Committee of Ethics in Medical Research (2016/2159). Patient consent was not required as the regional ethical committee found that the conditions for exemption from the duty of confidentiality was met. The project was considered of significant importance for society, and the welfare and integrity of the patients was ensured.

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