The effect of emergency department delays on 30-day mortality in Central Norway

Andreas Asheim[a,b,*], Sara Marie Nilsen[a,*], Fredrik Carlsen[c], Lars Eide Næss-Pleym[d,e], Oddvar Uleberg[d], Jostein Dale[d], Lars P. Bache-Wiig Bjørnsen[d,f] and Johan Håkon Bjørngaard[g,h]

Objective: **To assess whether prolonged length of stay in the emergency department was associated with risk of death.**

Methods: **We analysed data from 165,183 arrivals at St. Olav's University Hospital's emergency department from 2011 to 2018, using an instrumental variable method. As instruments for prolonged length of emergency department stay, we used indicators measured before arrival of the patient. These indicators were used to study the association between prolonged length of emergency department stay and risk of death, being discharged from the emergency department and length of hospitalisation for those who were hospitalised.**

Results: **Mean length of stay in the emergency department was 2.9 hours, and 30-day risk of death was 3.4%. Per hour prolonged length of stay in the emergency department, the overall change in risk of death was close to zero, with a narrow 95% confidence interval of –0.5 to 0.7 percentage points. Prolonged emergency department stay was associated with a higher probability of being discharged from the emergency department without admission to the hospital. We found no substantial differences in length of hospitalisation for patients who were admitted.**

Conclusion: **In this study, prolonged emergency department stay was not associated with increased risk of death. *European Journal of Emergency Medicine* 26: 446–452 Copyright © 2019 The Author(s). Published by Wolters Kluwer Health, Inc.**

European Journal of Emergency Medicine 2019, **26**:446–452

Keywords: emergency care, quality of health care, mortality

[a]Center for Health Care Improvement, St. Olav's hospital HF, [b]Department of Mathematical Sciences, Norwegian University of Science and Technology, [c]Department of Economics, Norwegian University of Science and Technology, [d]Department of Emergency Medicine and Pre-hospital Services, St. Olav's hospital HF, [e]Department of Research and Development, Norwegian Air Ambulance Foundation, [f]Department of Circulation and Medical Imaging, Norwegian University of Science and Technology, [g]Department of Public Health and Nursing, Norwegian University of Science and Technology, Trondheim and [h]Faculty of Nursing and Health Sciences, Nord University, Levanger, Norway

Correspondence to Sara Marie Nilsen, PhD, Regionalt senter for helsetjenesteutvikling, St. Olavs hospital, Postboks 3250 Sluppen, N-7006 Trondheim, Norway
Tel: +47 90867025; fax: +47 73597577; e-mail: sara.marie.nilsen2@stolav.no

Please add a contribution statement:

*Andreas Asheim and Sara Marie Nilsen contributed equally to the writing of this article.

Received 22 February 2019 **Accepted** 29 April 2019

Introduction

Emergency departments (EDs) serve as the primary entry point into hospitals for acutely ill or injured patients. Patients are prioritised according to a triage system [1,2], and either admitted to the hospital for further work-up and treatment, or discharged from the ED. Transient increases in the number of acutely ill or injured patients can lead to a strained service. This has been the subject for several studies, often with emphasis on delayed care and impaired patient safety as a consequence [3]. Delays in the ED could negatively affect patient safety through time to required in-hospital treatment or concurrency conflicts [4]. Even though patients with the most critical conditions are prioritised, crowding has been shown to delay treatment, prolonging ED stay, also among high acuity patients [5].

While information on the patient's length of stay in the ED is often available, prolongation of ED stay cannot be reliably measured directly from observational data. Length of stay in the ED would mostly reflect the prioritising between patients with different need of urgent treatment. Whether a patient is prioritised or not, there is a possibility that parts of the stay in the ED are unnecessary, for example waiting time due to a strained ED. Adjusting for medical prioritisation may in principle distinguish necessary from unnecessary parts of the ED stay. However, since data on the patient characteristics that are relevant for prioritisation are limited such adjustments are not feasible [6]. We propose using indicators measured before arrival as an instrument for prolonged length of stay in the

Supplemental Digital Content is available for this article. Direct URL citations appear in the printed text and are provided in the HTML and PDF versions of this article on the journal's website, www.euro-emergencymed.com.

0969-9546 Copyright © 2019 The Author(s). Published by Wolters Kluwer Health, Inc. DOI: 10.1097/MEJ.0000000000000609

ED in an instrumental variable analysis to study patient outcomes. Such analyses can under defined assumptions obtain causal estimates of the effect of prolonged length of stay without relying on statistical adjustments [7].

The aim of this study was to assess whether prolonged length of stay could negatively affect patient safety.

Methods

Study design and setting

This is a cohort study from the St. Olav's University Hospital, which is a publicly owned Norwegian academic teaching hospital with the local geographical responsibility for about 280 000 inhabitants and the regional function for Central Norway covering a population of about 700 000 inhabitants. One distinct characteristic of the Norwegian health care system is that the general practitioners are considered the gatekeepers for further specialised health care. Patients arriving at the ED have usually been evaluated and referred by a general practitioner or an out-of-hours primary services physician. Hence the number of arrivals is lower, and the proportion of patients hospitalised is high (84%) compared to international studies. Patients under the age of 16 and patients eligible for bypass protocols, for example percutaneous coronary intervention and fast-track hip fractures, are not usually evaluated in the ED. The clinical setting is described elsewhere [8,9].

Selection of participants and data collection

There were 171 842 arrivals recorded between 1 January 2011 and 31 December 2018. Removing incomplete registrations left 165 183 arrivals by 80 617 patients for the main analysis. See attached flowchart, Supplementary Fig. 1, Supplemental digital content 1, *http://links.lww.com/EJEM/A240* for details.

Time of arrival, triage and leaving the ED, as well as triage level, was obtained from the local ED database, Akuttdatabasen (Version 1.5.5.; Helse-Vest IKT, Stavanger, Norway). Patient characteristics and diagnoses were obtained from the hospital patient administration system, including date of death from the National Registry obtained by linking on personal identification number which is given to all Norwegian citizens at birth. Date of death was therefore not limited to in-hospital deaths.

Analytical strategy

An initial analysis was performed to assess the association between length of stay in the ED and risk of death within 30 days without adjustments, with the aim of demonstrating the degree to which this association was confounded.

The main analysis was based on an instrumental variable analysis. Such analyses rely on variables, referred to as instruments, with similar characteristics as the randomisation in a randomised trial. These instruments should provide variation in the exposure of interest, i.e., in prolonged length of ED stay in this study. An important prerequisite is that instruments must be independent of patient characteristics. We used two indicators as candidate instruments for a prolonged ED stay, computed using data collected at time of triage from the patient population triaged within a 3-hour long window, ending 15 minutes before patient arrival, as illustrated in Fig. 1. Thus, these instrumental variables for a prolonged ED stay were measured before the index patient could influence the condition at the ED, which would have induced dependence between characteristics of the index patient and the situation at the ED. The 15-minute gap was used to account for possible inaccuracies of manually registered timestamps [10,11]. To further substantiate the assumption of independence, we also tested whether these instrumental variables were associated with measured patient characteristics.

The association between the instrumental variables and length of stay in the ED should be positive. This was tested, including for subgroups of the patient population. Provided the instrumental variables were independent of patient condition, the variation in ED length of stay predicted by the instrumental variables could be assumed to be due to prolonged stay in the ED.

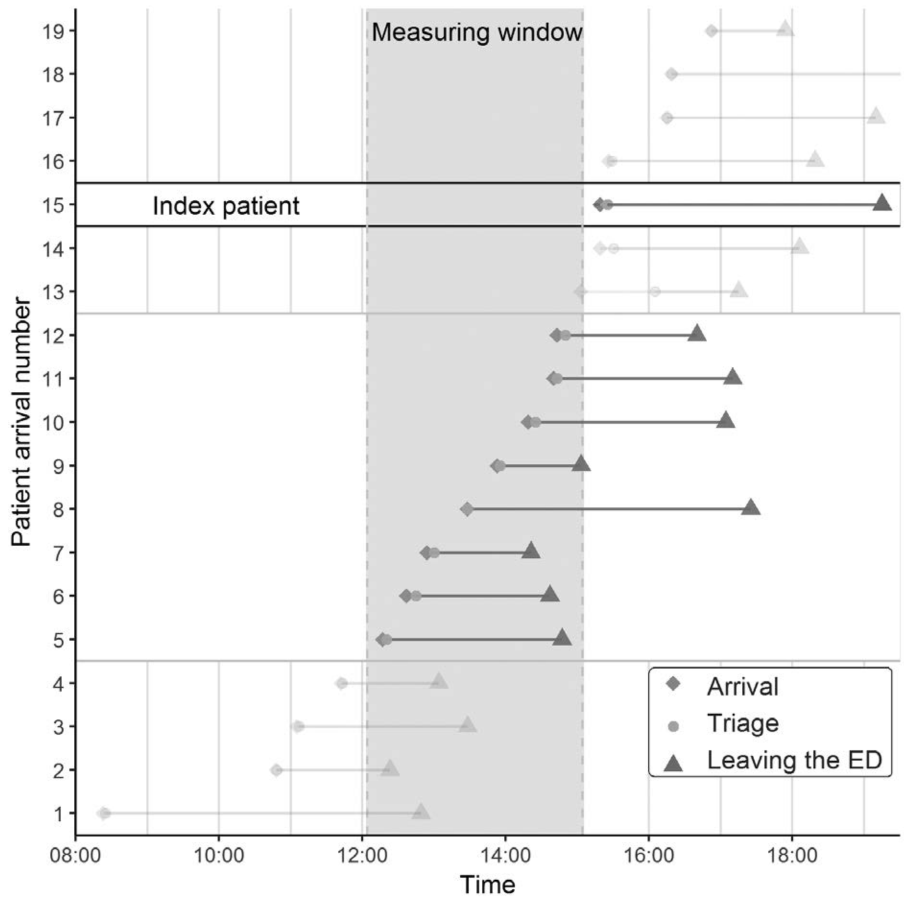
We used two indicators as candidate instruments to predict the exposure of interest, i.e. length of ED stay. The first indicator of the situation at the ED was the average time to triage in minutes. Triage is a prioritised task, and a longer time to triage indicates issues with crowding and possible prolonged length of ED stay for arriving patients. Secondly, we used the number of patients triaged as red. For every red patient present, a non-red patient is prioritised lower, possibly leading to prolonged length of ED stay for arriving patients.

Measurements

Length of stay in the ED was the difference between time of arrival and time of leaving the ED, measured in hours. Time-to-triage was measured as the difference between time of arrival and time of triage in minutes. Out of five triage levels in the Rapid Emergency Triage and Treatment System [1,2,9], patients with the presumed highest acuity level received the colour red. All patients were assigned a presumed medical specialty before arrival based on the chief complaint or a physician's referral note. This specialty may change based on the evaluation of an emergency physician or on-call physician on arrival at the ED. Specialty was categorised as medicine, surgery, orthopaedics, cancer, neurology, gynaecology and other. We had access to the last triage level and last medical specialty assigned during the ED stay.

The primary outcome was death within 30-days, measured from the time of arrival at the ED. Secondary outcomes were length of hospital stay among those admitted for further hospital treatment, and the probability of being treated and discharged from the ED. Length of hospital stay was calculated as the difference between time of

Fig. 1



Time of arrival (◆), triage (●) and leaving emergency department (ED), either admitted to the hospital or discharged from the ED (▲), are plotted from actual data for the patients arriving on a given day. With the 15th patient of the shift serving as example index patient, we see that arrivals 5–12 are being selected for computing instrumental variables for prolonged stay at triage.

admission to the hospital and time of discharge. Figures for risk of death after 10- and 60-days are included in the Supplementary Figs. 2 and 3, Supplemental digital content 1, *http://links.lww.com/EJEM/A240*.

The analyses were performed for the total patient population and for patients under and over 80 years old, men and women. We also did the analysis before and after the midpoint of the data material, 1 January 2015, to investigate whether the results were stable over time. In addition, we did subgroup analyses of patients with cardiovascular disease (CVD) and infections, since these are presumably sensitive to timing of treatment. A patient was coded as having CVD if having been hospitalised within 48 hours of the ED arrival and given a primary diagnosis from the I-chapter of ICD10. Similarly, a patient was coded with infectious disease if, within 48 hours, given any diagnosis indicating a bacterial infection as primary or secondary diagnosis, as described in Supplementary Table 1, Supplemental digital content 1, *http://links.lww.com/EJEM/A240*.

Statistics

The instrumental variable analysis was done using two-stage ordinary linear regression with robust standard errors using the package ivpack (version 1.2, Yang Jiang and Dylan Small) in RStudio (version 1.1.442; Free Software Inc., Boston, Massachusetts, USA), giving estimates of change in absolute 30 days risk of death per hour of prolonged length of stay. The models were adjusted for age in 1-year intervals, 30-days prior admissions, medical specialty, arrival hour in 1-hour categories, weekday, holiday, day after holiday, and month-year. Adjusting for the combination of month and year gave 96 dummy variables. This approach captures possible seasonal variations, as well as persistent organisational changes, since only within-year-and-month-variability will contribute to the results.

Testing instrumental variable assumptions

For the analysis to be valid, the instrumental variables must be independent of the patient's condition. We tested for the independence by calculating the association between the instrumental variables and age, sex, CVD- and infection diagnoses, arrival by ambulance and the main medical specialties. These analyses were adjusted for time variables as in the main analysis.

The association between the instrumental variables and length of stay in the ED was tested by linear regression, including for the subgroups in the main analysis. We recorded the partial F-statistics of the adjusted association between the indicators and ED length of stay, which indicates the strength of the association. We performed Sargan's test, where rejecting the null hypothesis would indicate that at least one of the instruments is not valid [12].

Ethics

The use of patient data was approved by Norwegian Centre for Research Data, ref. no. 59265. The regional ethics committee (REK) was informed about the study, and they evaluated the study not in need of a formal REK approval, reference number 2018/247.

Results

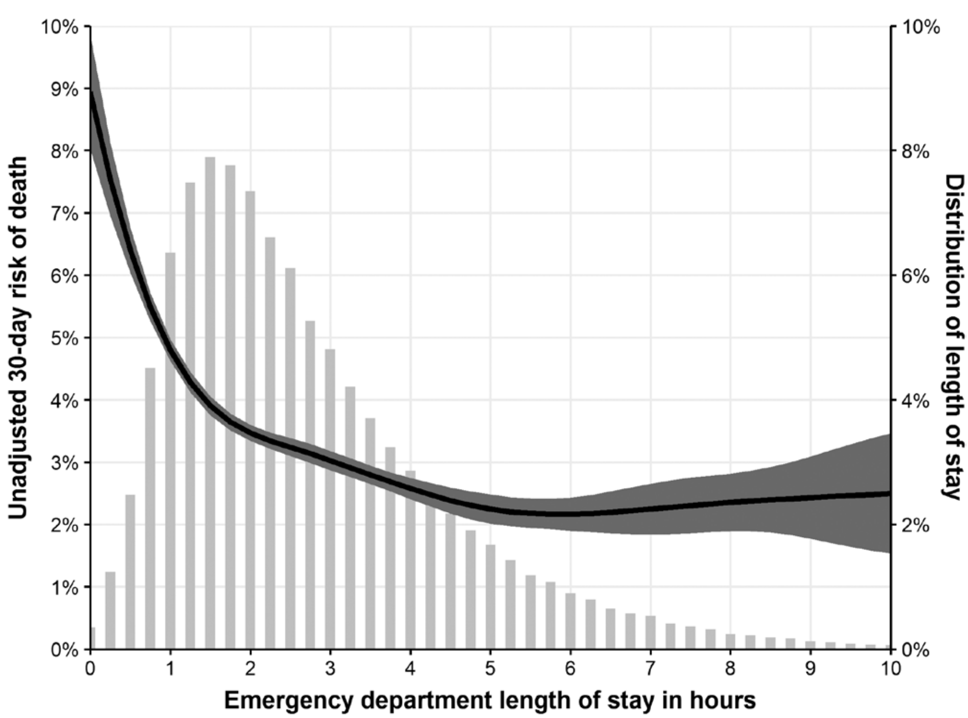
A table summarising characteristics of the index population is included in Supplementary Table 2, Supplemental digital content 1, *http://links.lww.com/EJEM/A240*. The average length of stay in the ED was 2.9 hours with a SD of 1.8 hours. Risk of death within 30 days was 3.4%.

Figure 2 gives a picture of the result of the initial analysis, the association between length of stay in the ED and risk of death within 30-days, as well as the distribution of length of stay. Simply comparing patients with different length of stay in the ED shows around 6% risk of death for patients who stayed for less than one hour, with a considerable reduction in risk as the length of ED stay increased.

Table 1 summarises the test of independence for the instrumental variables. We observed no substantial associations.

There was a strong association between the instrumental variables and length of ED stay for arriving patients. Per 10-minute increase in average time to triage in the measuring window, we found 7.6 minutes (95% CI, 7.2 to 8.0) prolonged length of stay in the ED for arriving patients. Correspondingly, we found 5.6 minutes (95% CI, 5.1 to 6.0) prolonged length of stay in the ED per red patient. The association between the instrumental variables and length of ED stay was strong across subgroups (Supplementary Table 3, Supplemental digital content 1, *http://links.lww.com/EJEM/A240*). The partial F-statistic of the association between the instrumental variables and length of stay in the ED was 840. Sargan's test yielded a P value of 0.4, indicating valid instruments.

Fig. 2



Histogram of length of emergency department (ED) stay. The initial analysis of the association between length of ED stay and risk of death within 30-days is plotted in black with 95% confidence interval in grey.

Table 1 Test of instrument independence assumptions

Potential confounder	Coefficient (95% CI)	*P* value
Instrument: average time to triage		
Age, per 10 years	−0.02 (−0.04 to 0.01)	0.21
Sex	−0.02 (−0.12 to 0.09)	0.74
Cardiovascular disease	0.01 (−0.14 to 0.16)	0.90
Infection	−0.08 (−0.23 to 0.07)	0.32
Ambulance	−0.26 (−0.63 to 0.11)	0.17
Medical speciality: medicine	0.09 (−0.02 to 0.20)	0.09
Medical speciality: orthopaedics	0.02 (−0.18 to 0.22)	0.84
Medical speciality: surgery	−0.05 (−0.18 to 0.07)	0.40
Medical speciality: neurology	−0.16 (−0.34 to 0.02)	0.09
Instrument: number of red patients		
Age, per 10 years	−0.00 (−0.00 to 0.00)	0.16
Sex	0.00 (−0.01 to 0.01)	0.55
Cardiovascular disease	−0.01 (−0.02 to 0.01)	0.39
Infection	−0.01 (−0.03 to 0.00)	0.13
Ambulance	−0.02 (−0.05 to 0.02)	0.33
Medical speciality: medicine	−0.00 (−0.01 to 0.01)	0.50
Medical speciality: orthopaedics	0.01 (−0.01 to 0.03)	0.36
Medical speciality: surgery	−0.01 (−0.02 to 0.01)	0.35
Medical speciality: neurology	0.01 (−0.01 to 0.03)	0.16

Association between the instrumental variables and potential confounders. Adjusted for time variables.

The main results of this study are summarised in Fig. 3, showing that the estimated change in risk of death within 30 days per hour prolonged length of ED stay was 0.01 percentage points (95% CI, −0.51 to 0.54). The estimates for the subcategories were also close to zero.

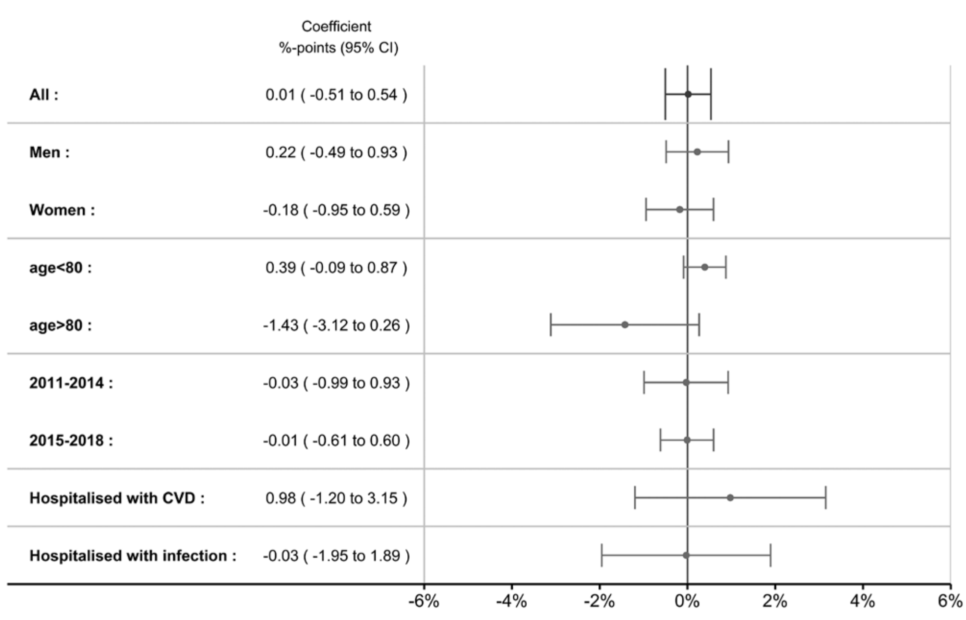
Figure 4 shows the risk of being treated and discharged from the ED. Prolonged stay generally translates to a lower probability of being admitted into the hospital. However, we observed no differences in length of hospitalisation for patients who were admitted (Supplementary Fig. 4, Supplemental digital content 1, *http://links.lww.com/EJEM/A240*).

Discussion

In this study we found no overall association between prolonged ED stay, and risk of death within 30 days. Neither did the subgroup analysis for patient groups presumably sensitive to timing of treatment reveal any apparent risk increase. The probability of being discharged from the ED was higher with prolonged ED stay, but there was no effect on hospital length of stay for those admitted.

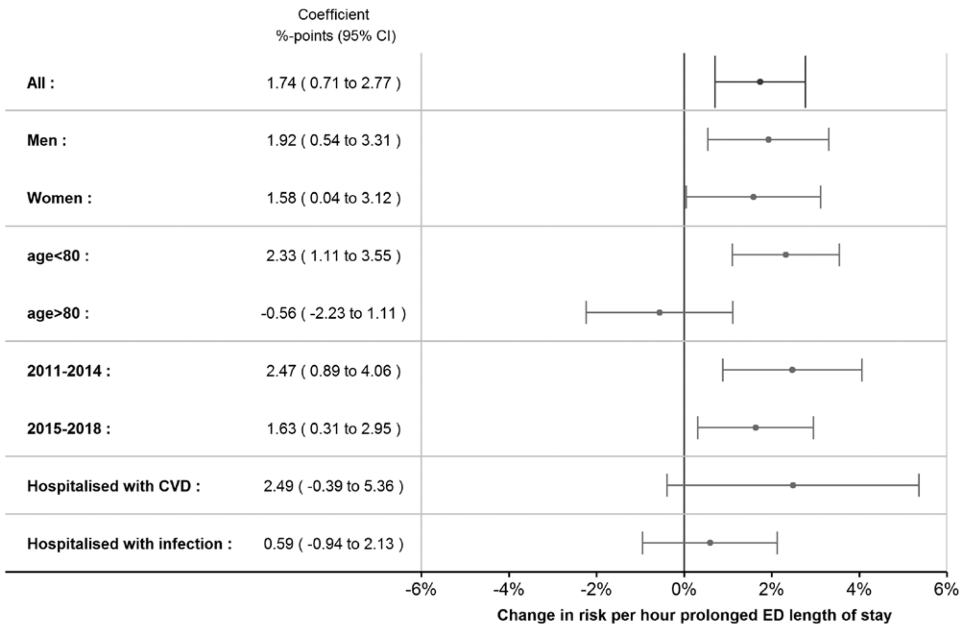
When studying the effect of prolonged length of ED stay on risk of death or other outcomes, it's important to ensure that the results are not influenced by prioritisation between patients. A systematic review from 2011 identified 71 unique crowding measures [13], but independence from the index patient's condition was not discussed. Similarly, measures that are validated for measuring crowding, like ICMED [14] and NEDOCS [15] were not designed with this in mind. By including patients concurrent to the index patient in the crowding measures, estimates of the effect of crowding on risk of death may be confounded by the index patient's condition. If a highly prioritised patient leads resources away from concurrent patients, such analyses will be skewed towards a stronger effect of crowding.

Fig. 3



Change in risk of death within 30 days per hour prolonged emergency department (ED) stay, with 95% confidence intervals. Adjusted for time variables, medical specialty, readmissions, age with dummy variables for each 1-year age interval and sex.

Fig. 4



Risk of being treated and discharged from the emergency department (ED) per hour prolonged ED stay, with 95% confidence intervals. Adjusted for time variables, medical specialty, readmission, age with dummy variables for each 1-year age interval and sex.

We measured the condition of the ED before the arrival of the index patient, such that the patient condition is not likely to affect the crowding measure. Further, we justified the assumption that our instruments for prolonged stay were independent of the index patient's condition with a balance test against possible confounders. While several previous studies have investigated the effect of crowding on risk of death through variants of length of ED stay [16–18], those studies did not justify the independence assumptions of their crowding measures.

Previous studies have mainly been concerned with crowding, delayed care and patient safety for patients who were admitted to hospital and have largely used risk of within-hospital death as outcome [19]. In-hospital risk of death could be influenced by selection bias, since patients with different length of stay have different time at risk.

For patients who are exposed to ED delays, every stage of the patient visit may be affected. Since the instruments used to predict length of ED stay are mainly concerned with patient input, namely time to triage and the number of red patients, we can expect that our results are more strongly related to time to initial treatment and assessment than boarding time. Our finding is consistent with a recent Dutch study [20], which reported an association between ED crowding and increased time to triage and treatment, but no substantial change in risk of death within 24-hours or 10-days.

We observed no apparent effect on hospital length of stay for the hospitalised patients, which could have indicated more complications with prolonged ED stay. This result further supports no substantial effects on patient safety of prolonged ED stay in our material.

We found a lower probability of being hospitalised with prolonged length of ED stay. This could be a consequence of time spent on patient work-up in the ED. Patients suitable for discharge are usually detected at the initial evaluation of the patient (triage), and length of stay in the ED depends on available diagnostic modalities. More time for observations and testing is associated with less hospitalisation, also if the prolongation is not due to medical reasons.

The results should be interpreted with the Norwegian health care system as a backdrop and cannot be readily generalised. We provide R-code (Supplementary Digital Content Text 1, Supplemental digital content 1, *http://links.lww.com/EJEM/A240*) so that the analysis may easily be replicated in other settings.

We conclude that, in our study, prolonged ED stay was not associated with increased risk of death.

Acknowledgements

S.M.N. was funded by the Norwegian research council, Grant number 256579.

Conflicts of interest

There are no conflicts of interest.

References

1 Widgren BR, Jourak M. Medical emergency triage and treatment system (METTS): a new protocol in primary triage and secondary priority decision in emergency medicine. *J Emerg Med* 2011; **40**:623–628.
2 Predicare. 2019. About RETTS. Available at: http://predicare.eu/about-retts/. [Accessed 14 May 2019]
3 Morley C, Unwin M, Peterson GM, Stankovich J, Kinsman L. Emergency department crowding: a systematic review of causes, consequences and solutions. *Plos One* 2018; **13**:e0203316.
4 Diercks DB, Roe MT, Chen AY, Peacock WF, Kirk JD, Pollack CV Jr, *et al*. Prolonged emergency department stays of non-ST-segment-elevation myocardial infarction patients are associated with worse adherence to the American College of Cardiology/American Heart Association guidelines for management and increased adverse events. *Ann Emerg Med* 2007; **50**:489–496.
5 McCarthy ML, Zeger SL, Ding R, Levin SR, Desmond JS, Lee J, Aronsky D. Crowding delays treatment and lengthens emergency department length of stay, even among high-acuity patients. *Ann Emerg Med* 2009; **54**:492–503.e4.
6 Hernán MA, Robins JM. *Causal Inference*. Boca Raton, Florida: Chapman & Hall/CRC, forthcoming; 2019.
7 Greenland S. An introduction to instrumental variables for epidemiologists. *Int J Epidemiol* 2000; **29**:722–729.
8 Bjørnsen LP, Uleberg O, Dale J. Patient visits to the emergency department at a Norwegian University Hospital: variations in patient gender and age, timing of visits, and patient acuity. *Emerg Med J* 2013; **30**:462–466.
9 Langlo NM, Orvik AB, Dale J, Uleberg O, Bjørnsen LP. The acute sick and injured patients: an overview of the emergency department patient population at a Norwegian University Hospital Emergency Department. *Eur J Emerg Med* 2014; **21**:175–180.
10 Gorlicki J, Raynal PA, Leleu A, Riou B, Ray P, Freund Y. Reliability of electronic recording of waiting times in the emergency department: a prospective multicenter study. *Eur J Emerg Med* 2015; **22**: 366–369.
11 Lillebo B, Seim A, Vinjevoll OP, Uleberg O. What is optimal timing for trauma team alerts? A retrospective observational study of alert timing effects on the initial management of trauma patients. *J Multidiscip Healthc* 2012; **5**:207–213.
12 Davies NM, Smith GD, Windmeijer F, Martin RM. Issues in the reporting and conduct of instrumental variable studies: a systematic review. *Epidemiology* 2013; **24**:363–369.
13 Hwang U, McCarthy ML, Aronsky D, Asplin B, Crane PW, Craven CK, *et al*. Measures of crowding in the emergency department: a systematic review. *Acad Emerg Med* 2011; **18**:527–538.
14 Boyle A, Coleman J, Sultan Y, Dhakshinamoorthy V, O'Keeffe J, Raut P, Beniuk K. Initial validation of the international crowding measure in emergency departments (ICMED) to measure emergency department crowding. *Emerg Med J* 2015; **32**:105–108.
15 Weiss SJ, Derlet R, Arndahl J, Ernst AA, Richards J, Fernández-Frankelton M, *et al*. Estimating the degree of emergency department overcrowding in academic medical centers: results of the National ED Overcrowding Study (NEDOCS). *Acad Emerg Med* 2004; **11**:38–50.
16 Derose SF, Gabayan GZ, Chiu VY, Yiu SC, Sun BC. Emergency department crowding predicts admission length-of-stay but not mortality in a large health system. *Med Care* 2014; **52**:602–611.
17 Gabayan GZ, Derose SF, Chiu VY, Yiu SC, Sarkisian CA, Jones JP, Sun BC. Emergency department crowding and outcomes after emergency department discharge. *Ann Emerg Med* 2015; **66**:483–492.e5.
18 Singer AJ, Thode HC Jr, Viccellio P, Pines JM. The association between length of emergency department boarding and mortality. *Acad Emerg Med* 2011; **18**:1324–1329.
19 Eriksson CO, Stoner RC, Eden KB, Newgard CD, Guise JM. The association between hospital capacity strain and inpatient outcomes in highly developed countries: a systematic review. *J Gen Intern Med* 2017; **32**:686–696.
20 van der Linden N, van der Linden MC, Richards JR, Derlet RW, Grootendorst DC, van den Brand CL. Effects of emergency department crowding on the delivery of timely care in an inner-city hospital in the Netherlands. *Eur J Emerg Med* 2016; **23**:337–343.