Comparing the dangers of a stay in English and German hospitals for high-need patients

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ABSTRACT

Objective: To estimate the risk of an avoidable adverse event for high-need patients in England and Germany and the causal impact that has on outcomes.

Data sources: We use administrative, secondary data for all hospital inpatients in 2018. Patient records for the English National Health Service are provided by the Hospital Episode Statistics database and for the German health care system accessed through the Research Data Center of the Federal Statistical Office.

Study design: We calculate rates of three hospital acquired adverse events and their causal impact on mortality and length of stay through propensity score matching and estimation of average treatment effects.

Data collection/extraction methods: Patients were identified based on diagnoses codes and translated Patient Safety Indicators developed by the Agency for Healthcare Research and Quality.

Principal findings: For the average hospital stay, the risk of an adverse event was 5.37 percent in the English National Health Service and 3.26 percent in the German health care system. High-need patients are more likely to experience an adverse event, driven by hospital acquired infections (2.06 percent to 4.45 percent), adverse drug reactions (2.37 percent to 2.49 percent) and pressure ulcers (2.25 percent to 0.45 percent). Adverse event risk is particularly high for patients with advancing illnesses (10.50 percent to 27.11 percent) and the frail elderly (17.75 percent to 28.19 percent). Compared to the counterfactual, high-need patients with an adverse event are more likely to die during their hospital stay and experience a longer length of stay.

Conclusions: High-need patients are particularly vulnerable with an adverse event risking further deterioration of health status and adding resource use. Our results indicate the need to assess the costs and benefits of a hospital stay, particularly when care could be provided in settings considered less hazardous.

Callout Box

What is known on this topic (3 short bullet points):

- Patient safety has been enshrined as a global health priority via a World Health Assembly Resolution in 2019, and many health systems in high income countries have focussed on safety for over 20 years.
- Adverse events are a leading cause of morbidity and mortality with more than 23 million disability-adjusted life years lost globally every year.
- The likelihood of an adverse event increases with patient complexity and the frequency of interaction with the health care system, suggesting that high-need patients may be disproportionately affected by patient safety failures.

What this study adds (3 short bullet points):

- Despite significant differences in the way patient safety was addressed in the English National Health Service and German health care system, overall rates of adverse events differ only slightly.
- On average, high-need patients are significantly more likely to experience one of three avoidable adverse events, subsequently increasing their morality risk and health service resource use.
- Policy makers should consider the costs and benefits of a hospital stay for high-need patient groups, particularly when care could be provided outside the hospital environment, or as a shorter length of stay.

INTRODUCTION

Health care systems across the world strive towards offering high quality care to all patients. This includes providing services in an environment that is safe to enable patients to regain the strength required to recover from poor health. However, every hospital stay is associated with a significant risk to experience harm that could lead to permanent disability, or death.[1–7] Since the publication of "To Err is Human" by the Institute of Medicine in 1999,[8] efforts have been made to quantify the risk associated with hospital stays and to determine its underlying causes, with the aim to guide strategies to improve the patient safety of hospital care.[9] Approximately 15 percent of hospital expenditures and activity in Organisation for Economic Co-operation and Development countries is attributed to addressing safety failures, and most of the financial burden relates to adverse events, specifically infections, venous thromboembolism, pressure ulcers, medication errors, and incorrect or delayed diagnoses.[10] Over the past 30 years, the global, age-standardized incidence of adverse events has increased by more than 30 percent, to 438.97 per 100,000 population in 2017.[11] An estimated 23 million disability-adjusted life years are lost every year,[12] ranking adverse events as the 14th leading cause of morbidity and mortality in the world.[13] One in every twenty hospital patient suffers preventable harm as part of their hospital stay,[14] which could be addressed through an improved patient safety culture, adoption of evidence-based practices, and better organisational structures.

Patient safety has become a priority across many health systems in the world, although policy approaches to lower rates of avoidable harm vary widely. For example, the English National Health Service (NHS) has a history of engaging with medical injuries and patient outcomes going back to efforts made by Florence Nightingale in the 19th century.[15] Adverse events were first addressed as a systematic problem in the 2000 Department of Health report "An Organisation With A Memory",[16] which was followed by the establishment of the National Patient Safety Agency tasked with collecting and analysing data about adverse events, including medication and prescribing errors.[17] The focus on patient safety was furthered by high-profile public inquiries into hospital failings due to poor quality of care, including the Francis Report.[18] Over the last ten years, the United Kingdom government has implemented several patient safety strategies,[19] created a ministerial role to oversee patient safety in the NHS and implemented regulation that provides a statutory candour for health professionals.

In Germany, patient safety has been the focus of the federal government and its self-governing bodies since the early 2000s. This has led to the implementation of extensive statutory quality

and safety requirements and quality assurance obligations (*i.e.*, external quality assurance and internal quality management), including minimum services volumes for selected hospital services.[20] Since 2000, hospitals are obliged to collect quality measures that allow for comparisons through the standardized documentation of quality indicators,[21] for instance in cardiac surgery, hip and knee replacement, transplantation, pacemaker implantation, and prevention of pressure ulcers. Results are made available to hospitals through reports and recommendations, requiring underperforming providers to explain and, if necessary, take appropriate action to improve performance. Since 2005, hospitals must publish standardized quality reports, including information on hospital structure, processes, and details regarding their internal quality management system. In the same year, the German Coalition for Patient Safety was established,[22] a multidisciplinary network consisting of representatives from providers, sickness funds, and patient groups to jointly develop recommendations for action to promote patient safety. Further developments aimed at strengthening the quality assurance system include the establishment of the Institute for Quality and Transparency in Health Care (IQTIG) in 2015, and the launch of initiatives such as 'quality assurance with routine data', the 'quality medicine initiative', and 'quality clinics', initiated by sickness funds or private hospital chains.[23] However, unlike the English NHS, Germany has no systematic comparative public system in place that allows for scrutiny of adverse events at provider-level; instead, a few initiatives by health insurers or foundations provide some information for patients.

Adverse events almost always occur in combination with an underlying health condition[24] and correlate with length of stay.[25] The overall risk for an adverse event appears highest for complex and more clinically severe types of patients,[26] with a study from Australia estimating that each additional night in hospital increases the risk of an adverse event between 0.5 percent and 1.6 percent.[25] It is therefore possible that the burden of adverse events is disproportionately affecting high-need patients (*i.e.*, patients with high utilisation of health care services due to a complex disease profile), considering their higher frequency of hospitalisation, characterised by complex care needs and longer length of stay.[27] In the United States, more than 10% of Medicare beneficiaries are considered high-need, cumulatively contributing to more than one third of health expenditure.[28,29] Despite the salience of this issue to policy makers and the possible implications for health service use and costs in this patient group, no study has investigated the risk of adverse events in high-need patients at a system-level. Our study investigates the prevalence of three common, and potentially preventable adverse events (*i.e.*, adverse drug reaction, infections, and pressure ulcers) and the causal impact that has on patient outcomes in

the English NHS and German health care system. Our findings can inform the development of effective strategies to improve care pathways for high-need patients with an aim to lower the burden on health system resources.

METHODS

Study cohort

To obtain patient-level information for all hospital inpatients admitted and discharged in the English NHS in calendar year 2018, we accessed the Hospital Episode Statistics (HES) database provided by NHS Digital (*i.e.*, the non-departmental public body responsible for information, data and IT systems in England). This database contains detailed information from pseudonymised patient records, including for patients accessing care at Accident and Emergency departments, as hospital inpatients and in outpatient settings. For each patient, we retrieved demographic characteristics, diagnosis information, procedures performed and in-hospital death. HES data is structured in finished episodes of care, which are linked to a clinician responsible for a respective aspect of the care pathway. To assess the risk of adverse events during the entirety of the hospital stay, we combined all episodes from day of admission to the day of discharge into spells, which also accounts for provider transfers if part of the same treatment plan. To ensure comparability with the German data, we excluded day-case admissions (*i.e.*, commonly an elective admission without intent for overnight stay) from the HES data, identified through the patient classification code.

For the German health care system, we obtained unidentifiable patient-level data for all patients treated in German hospitals from the Research Data Centre of the Federal Statistical Office (DRG statistics)[30]. The DRG statistics include all full inpatient hospital cases within Germany. The data are collected by the Institute for the Hospital Remuneration System (InEK) taken from data records submitted by hospitals for billing purposes. The data is structured to reflect the reimbursement of patient care for each individual hospital stay (*i.e.*, excluding day-case admissions that are commonly provided in ambulatory care settings), entailing all diagnoses and procedures recorded in the period from admission to discharge. Through the DRG statistics we obtained information on patient demographics, clinical pathways, and outcomes comparable to the HES in England. In both datasets, we included individuals who are 18 years, or older.

Study outcomes

Our study investigates the prevalence of three common, and potentially preventable adverse events: adverse drug reactions, infections, and pressure ulcers.[25] Identification of adverse events was based on relevant diagnosis codes according to the International Statistical Classification of Diseases and Related Health Problems, 10th edition (ICD-10). The selection of codes followed those used in previous studies as they have shown high validity and specificity in the detection of adverse events from electronic health records (see Appendix A). We applied relevant inclusion and exclusion criteria set out in the Patient Safety Indicators of the Agency for Healthcare Research and Quality to ensure the identification of hospital acquired adverse events from administrative patient records, which had been translated and validated for use in England.[31]

We identified high-need patients based on the definition provided by the National Academy of Medicine, formerly the Institute of Medicine in the United States of America.[28] These include five subgroups: non-elderly disabled; multiple chronic; major complex chronic; frail elderly; and advancing illness. Non-elderly disabled refer to patients aged below 65 years and with end stage renal disease. Multiple chronic describe patients with only one complex condition and/or between one and five non-complex conditions, whereas major complex chronic describe patients with two or more complex conditions or at least six non-complex conditions. We defined frail elderly as patients aged over 65 years and with a minimum of two frailty indicators. The identification of frailty indictors followed those validated based on HES data.[32,33] Advancing illness describes patients subject to palliative care.[29] As sensitivity analysis, we also defined high-need patients as those with four or more comorbidities captured by the Charlson Comorbidity Index.

The secondary outcomes studied are the patients' length of stay and in-hospital mortality. Length of stay was calculated as the difference between day of admission and day of discharge. Patients that were admitted and discharged on the same day, or without staying overnight were recorded with a zero length of stay (*e.g.*, when patients died on the admission day). We identified patients who died during their hospital stay based on the record of the discharge method.

Covariates

Both datasets included information on patient characteristics, including age, gender, comorbidity, number of procedures and type of admission (*i.e.*, emergency or elective). We used the Charlson Comorbidity Index as a measure for patient complexity based on the number of comorbidities

recorded in each admission.[34] This index is widely used for risk-stratification in health services research and was calculated based on diagnosis codes. We included patient groups with 0 comorbidities to 6 or more comorbidities, respectively. Our inclusion of covariates was guided by the availability of information across the English and German datasets, and we were therefore unable to include information on the patient's socio-economic status and ethnicity given that this information was not captured in the German data.

Statistical analysis

Descriptive statistics were used to report the proportion of adverse events in England and Germany in 2018, for the full sample and by high-need patient subgroup.

To estimate the probability of experiencing an adverse event in hospitals in England and Germany, we first used a multivariate patient-level, linear regression model to examine the relationship between patient characteristics and adverse events [1]. Previous literature showed that length of stay can raise some endogeneity bias. To overcome this problem, we added two time-variables (*i.e.*, weekdays versus weekend, and winter period, which have been used as instruments in a study by Hauck *et al.* (2011)). Although adverse events were binary, we used linear models to keep the interpretability of linear trends in experiencing an adverse event. We assigned hospital fixed effects to capture unobserved hospital characteristics (*e.g.*, unobserved hospital quality) and employed standard errors clustered at the hospital-level. We report p-values with 0.05 considered as a threshold for statistical significance. Our multivariate patient-level model had the following specification [1]:

$$Y_{ij} = \alpha + \beta X_{ij} + \gamma Z_{ij} + \delta H_{ij} + c_j + \mu_{ij} \text{ [1]}$$

where Y_{ij} indicates the outcome variable, whether the patient i experienced an adverse event in hospital j; X_{ij} is a vector of patient characteristics (*i.e.*, age, gender, Charlson Comorbidity Index, type of admission and number of operations); Z_{ij} denotes the time-variables (*i.e.*, weekdays versus weekend, and winter period); H_{ij} indicates the five subgroups of high-need patients (*i.e.*, non-elderly disabled; multiple chronic; major complex chronic; frail elderly; and advancing illness); c_j denotes hospital fixed-effects; $\alpha, \beta, \gamma \text{ and } \delta$ are unknown parameters and μ_{ij} is the normally distributed disturbance term.

To estimate the impact of adverse effects on in-hospital mortality and length of stay, we employed propensity score matching and estimated average treatment effects on the treated.[35] We first calculated propensity scores as the conditional probability of having an adverse event based on a combination of patient characteristics that fulfilled balancing properties, including age, gender, Charlson Comorbidity Index, and type of admission, using probit regression analysis. To ensure a counterfactual that is closely related to the patient experiencing an adverse event in terms of clinical diagnosis and expected outcomes, we further include the patient's DRG classification (*i.e.*, the first three digits) into the estimation. We then matched patients in the treatment and control group (*i.e.*, those with and without an adverse event) using the nearest neighbour matching method, which assumes that given balancing criteria are met, any effect on outcomes results from the exposure to the adverse event. As robustness checks, instead of using the patient's DRG classification, we rerun our analysis using the five subgroups of high-need patients and the ICD-10 chapter of the primary diagnosis, separately. All analyses were performed using STATA SE 16.

RESULTS

Adverse events in the English NHS and Germany

Our study sample for calendar year 2018 included 7,745,622 hospital inpatients in the English NHS, and 17,498,049 hospital inpatients in the German health care system (see table 1). Based on information recorded in electronic health records, we identified 415,983 (5.37 percent) adverse events in England, compared with 570,088 (3.26 percent) adverse events in Germany. The majority of adverse events related to infections, followed by adverse drug reactions and pressure ulcers (see figure 1). While the English NHS recorded a greater proportion of infections (2.80 percent versus 1.32 percent) and pressure ulcers (1.38 percent and 0.26 percent) compared with Germany, adverse drug reactions (1.65 percent versus 1.78 percent) were slightly more common in Germany.

We defined five high-need patient groups and calculated their associated adverse event rates for calendar year 2018. In the English NHS, we classed 0.44 percent of patients as non-elderly disabled, 43.41 percent as multiple chronic, 28.27 percent as major complex chronic, 2.07 percent as advancing illness, and 0.50 percent as frail elderly. In the German health care system, we classed 0.35 percent of patients as non-elderly disabled, 41.78 percent as multiple chronic,

25.98 percent as major complex chronic, 0.47 percent as advancing illness, and 0.94 percent as frail elderly.

On average, high-need patients were significantly more likely to experience an adverse event compared with those not classed as high-need. In the English NHS, 8.30 percent of high-need patients had an adverse event recorded, with 4.84 percent of high-need patients in Germany (see table 2). However, the adverse event risk differed between high-need patient groups, with patients with advancing illness and the frail elderly most likely to experience an adverse event. We found that in the English NHS, 27.11 percent of patients with advancing illness had an adverse event compared with 10.50 percent in Germany, whereas 28.19 percent of frail elderly patients had an adverse event compared with 17.75 percent, respectively. In England, infections were the most common form of an adverse event, whereas adverse drug events were most common in Germany.

Determinants of adverse events

Multivariate patient-level, linear regression models were used to estimate the association between patient characteristics and clinical characteristics on the risk of experiencing an adverse event. We found a similar pattern across health care systems in both countries (see figure 2 and appendix B). Males were less likely to experience an adverse event compared with women and risk increases in line with the number of comorbidities. Patients admitted as an emergency were more likely to experience an adverse event compared with elective admissions, as were patients admitted during the weekday. Our analysis showed that high-need patient groups are significantly more likely to experience an adverse event, with patients classed as advancing illness carrying greatest risk in England, and those classed as frail elderly carrying greatest risk in Germany.

Implication of adverse events on patient outcomes and health service use

We estimate the causal impact of an adverse event on patient outcome and health services use by employing patient-level, nearest neighbour matching based on calculated propensity scores. We find strong evidence to suggest that adverse events lead to a significant increased risk in in-hospital mortality and cause a longer length of stay compared with a counterfactual (see table 3). Results show that an adverse event raises mortality risk by 0.7 percent in the English NHS and 3.7 percent in Germany. Moreover, adverse events expand the length of stay by an average of 7 days in the English NHS and by 4 days in Germany. The robustness checks, presented in table 3, show similar results, in terms of sign and significance, when using the ICD-10 chapter or the five

subgroups of high-need patients instead of the DRG code. However, the magnitude of the average treatment effect on the treated was higher compared to the preferred model.

DISCUSSION

Patient safety is a key health policy concern across the world, considering that one in every ten patients experiences an adverse event when hospitalised, ranking adverse events as one of the leading causes of morbidity and mortality. Patient safety has been enshrined as a global health priority via a World Health Assembly Resolution in 2019,[36] with many health systems in high income countries focussing on safety with an aim to improve patient outcomes, to lower resource use and costs for over 20 years. However, the approaches used to address adverse events vary widely by country, which may reflect on the rate of adverse events experienced by patients. For example, the English NHS has seen a significant policy drive towards improving patient safety since 2000, including the establishment of a statutory body to collect and publicly report adverse events, as well as through high profile public enquiries into the failing of health care providers. Even though recent initiatives aiming to prepare quality data for patients in a user-friendly way (*e.g.*, health navigator of the AOK - a German sickness fund),[37] the German health care system has not yet implemented clear public reporting of adverse events beyond the information provided in hospital quality reports. However, based on our analysis of administrative data for all inpatients treated in the English NHS and German health care system, we find that the prevalence of the three selected adverse events is more common in the English NHS (5.37 percent of patients experience an adverse event), compared with Germany (3.26 percent of patients experience an adverse event). In England, adverse events are driven by infections (2.80 percent), followed by adverse drug reactions (1.65 percent), and pressure ulcers (1.38 percent). Interestingly, in Germany adverse events are driven by adverse drug reactions (1.78 percent), followed by infections (1.32 percent), and pressure ulcers (0.26 percent).

Previous research has suggested that the risk of an adverse event increases with patient complexity[26] and length of stay.[25] Due to their clinical profile and utilisation pattern, high-need patients are therefore particularly vulnerable, with an adverse event risking further deterioration of health status and adding complexity to patient care. To our knowledge, this is the first study to investigate the level of adverse events experienced by high-need patient groups across two health systems. We find that on average, high-need patients are significantly more likely to experience an adverse event compared with patients not defined as high-need, whereby frail elderly patients (28.19 percent in England and 17.75 percent in Germany), and those with an

advanced illness (27.11 percent in England and 10.50 percent in Germany) carry greatest risks. Moreover, patients who experienced an adverse event in 2018, on average spent additional time in hospital (7 days in England and 4 days in Germany), and were significantly more likely to die (0.7 percent in England and 3.7 percent in Germany). These findings highlight the need to carefully assess the costs and benefits of a hospital stay, particularly when care could be provided in less hazardous settings outside the hospital environment.

Strengths and limitations

Our study has limitations. We used administrative, patient-level data to identify adverse events and there may be residual error resulting from variation in coding practices between countries. Differences in policy focus on adverse events may influence on the number of adverse events recorded in administrative data,[38] as a function of clinician awareness and a culture that encourages recording of medical errors. However, both datasets are generally considered high quality, as they are derived from data used for hospital reimbursement, include all patients admitted as a hospital inpatient, and were used for the study of patient safety incidents,[6] as well as policy evaluations.[39,40] Our results are in line with previous predictions about the number of preventable adverse events in England,[41] and for adverse drug reactions, we find a trend reduction compared with data reported for both countries in 2006.[42] Moreover, using electronic health data sources for the identification of adverse events has been promoted as a way to assess patient safety incidents to overcome some of the limitations related to voluntary reporting, and retrospective record reviews.[43]

Even though there has been an increasing focus on the health service utilisation pattern of high-need patients, their definition varies across health care systems, and may even vary between insurers within the same health care system. For example, while high-need patients represent the most sick and complex populations, they may account for the top 1 percent to the top 20 percent of health care spending, with a plethora of underlying conditions that may include mental and behavioural disorders, circulatory diseases, and neoplasm.[44] We defined high-need patients according to the National Academy of Medicine,[29] with frailty codes previously validated on HES data.[32,33] Analyses were performed for all patients defined as high-need, and separately for each high-need subgroup. To assess the robustness of these findings, we performed sensitivity analyses by defining high-need patients as patients with four or more comorbidities captured by the Charlson Comorbidity Index. Our study findings were robust to varying

definitions, though high-need patients defined according to the Charlson Comorbidity Index showed higher levels of adverse events (13.48 percent in England and 7.21 percent in Germany).

We aimed to investigate the impact of adverse events on patient outcomes and health service use. Due to data limitations related to linking hospitalisations for individual patients across the study period, we were unable to assess patient outcomes such as hospital readmission rates,[45] and instead focussed on in-hospital mortality and length of stay. While both measures are widely used for the assessment of quality of care,[46,47] it is possible that adverse events resulted in significant deterioration of patient health with exacerbation of the post-hospital syndrome,[48] which could cause death or impact on patient reported outcomes[49] following patient discharge not captured in our data. Moreover, length of stay may be considered endogenous given previous findings but is also commonly used as a proxy for resource use and to reflect on severity.[50] To robustly estimate the causal impact of adverse events on both measures, we employed propensity score, nearest neighbour matching methods by generating a matched cohort based on observable characteristics, including patient demographics and clinical features. We further included information on discharge day and discharge month as covariates, because they had been used as instruments in a previous study.[25] Given that all our models met the key assumption of conditional independence and balancing properties in absence of randomisation, the estimated average treatment effect may be interpreted as the causal impact of an adverse event on patient mortality and length of stay.

Policy implications and conclusion

There are several reasons that could explain our findings. First, given that adverse event rates are driven by infections, the higher incidence in the English NHS compared with Germany may be directly related to hospital overcrowding.[51] A policy focus on improving efficiency in the NHS failed to address the growing mismatch between increases in demand for hospital services and hospital bed stock. As a result, the average bed occupancy rate has risen to levels considered unsafe (*e.g.*, above 92%), with many hospitals dealing with patient demands when fully occupied. Particular pressures on resource use in the NHS have been observed during the winter period, possibly explaining the association with adverse events observed in our analysis. Moreover, recent evidence has suggested that high bed occupancy impacts on A&E performance,[52] influences discharge processes and can lead to higher readmission rates for patient groups with most complex care needs.[53] Combined with low staffing levels,[54,55] high bed occupancy may also reduce compliance with patient safety programmes, such as hand washing, and promote greater

mobility between staff across hospital wards. In comparison to the NHS, the German health care system reports three times as many hospital beds.[56]

Second, we cannot discount the possibility that coding quality, or underreporting of adverse events is a key driver of the cross-country differences observed in this study. Particularly, variation in coding practices resulting from a non-relevance for hospital reimbursement, or those due to an enhanced focus, or lack thereof, on patient safety. As recognised by previous research, it is important to further promote recording various aspects of quality and prevent under-reporting of adverse events in routine data.[57]

Finally, some of the differences in adverse events, specifically adverse drug reactions may stem from variation in policy focus on patient safety. While the English NHS has seen extensive engagement with this topic through enquiries into hospital failings as well as initiatives that have supported the collection, analysis and public reporting of adverse events, the German health care system has abstained from public scrutiny of hospital performance with regards to patient safety. However, to strengthen transparency, the IQTIG is to publish quality comparisons of hospital services in the future so that patients can more easily obtain information about the quality of services and facilities when choosing a hospital. Additionally, planning-relevant quality indicators may be used for quality-oriented hospital planning decisions. However, it is unclear to what extent this has been applied in practice to date.[20]

Adverse events lead to avoidable patient harm, impact on patient's ability to recover from illness and increase health service resource use and costs. Our findings show that they are particularly common among high-need patient groups, with up to one in four palliative patients and frail elderly patients experiencing an adverse event. Based on the average cost of a day in hospital, excess length of stay due to adverse events may account for additional costs of almost $1.3 billion in England and Germany, respectively. As policy makers, hospital managers and clinicians are developing strategies to improve safety of hospital care, particular focus should be given to high-need patient groups, with improvements likely to yield significant benefits for patient outcomes and resource use.

REFERENCES

1. Eulmesekian PG, Alvarez JP, Ceriani Cernadas JM, Pérez A, Berberis S, Kondratiuk Y. The occurrence of adverse events is associated with increased morbidity and mortality in children admitted to a single pediatric intensive care unit. *Eur J Pediatr*. 2020;179(3):473-482. doi:10.1007/s00431-019-03528-z

2. Flaatten H, Brattebø G, Alme B, et al. Adverse events and in-hospital mortality: an analysis of all deaths in a Norwegian health trust during 2011. *BMC Health Serv Res*. 2017;17. doi:10.1186/s12913-017-2417-7

3. Haukland EC, Mevik K, Plessen C von, Nieder C, Vonen B. Contribution of adverse events to death of hospitalised patients. *BMJ Open Qual*. 2019;8(1):e000377. doi:10.1136/bmjoq-2018-000377

4. Greenberg MD, Haviland AM, Yu H, Farley DO. Safety Outcomes in the United States: Trends and Challenges in Measurement. *Health Serv Res*. 2009;44(2p2):739-755. doi:10.1111/j.1475-6773.2008.00926.x

5. Wang Y, Eldridge N, Metersky ML, et al. National Trends in Patient Safety for Four Common Conditions, 2005–2011. *N Engl J Med*. 2014;370(4):341-351. doi:10.1056/NEJMsa1300991

6. Hauck KD, Wang S, Vincent C, Smith PC. Healthy Life-Years Lost and Excess Bed-Days Due to 6 Patient Safety Incidents: Empirical Evidence From English Hospitals. *Med Care*. 2017;55(2):125-130. doi:10.1097/MLR.0000000000000631

7. Baker GR, Norton PG, Flintoft V, et al. The Canadian Adverse Events Study: the incidence of adverse events among hospital patients in Canada. *CMAJ*. 2004;170(11):1678-1686. doi:10.1503/cmaj.1040498

8. Institute of Medicine. *To Err Is Human: Building a Safer Health System*.; 1999. doi:10.17226/9728

9. Vincent C, Burnett S, Carthey J. *The Measurement and Monitoring of Safety: Drawing Together Academic Evidence and Practical Experience to Produce a Framework for Safety Measurement and*

Monitoring.; 2013. Accessed March 15, 2021. http://patientsafety.health.org.uk/sites/default/files/resources/the_measurement_and_monitoring_of_safety.pdf

10. Wagner C, Kristensen S, Sousa P, Panteli D. *Patient Safety Culture as a Quality Strategy*. European Observatory on Health Systems and Policies; 2019. Accessed March 15, 2021. https://www.ncbi.nlm.nih.gov/books/NBK549280/

11. Nauman J, Soteriades ES, Hashim MJ, et al. Global Incidence and Mortality Trends due to Adverse Effects of Medical Treatment, 1990–2017: A Systematic Analysis from the Global Burden of Diseases, Injuries and Risk Factors Study. *Cureus*. 12(3). doi:10.7759/cureus.7265

12. Jha AK, Larizgoitia I, Audera-Lopez C, Prasopa-Plaizier N, Waters H, Bates DW. The global burden of unsafe medical care: analytic modelling of observational studies. *BMJ Qual Saf*. 2013;22(10):809-815. doi:10.1136/bmjqs-2012-001748

13. Slawomirski L, Auraaen A, Klazinga N. The Economics of Patient Safety. *OECD*. 2017:65.

14. Panagioti M, Khan K, Keers RN, et al. Prevalence, severity, and nature of preventable patient harm across medical care settings: systematic review and meta-analysis. *BMJ*. 2019;366:l4185. doi:10.1136/bmj.l4185

15. Lim F. Why Florence Nightingale still matters. *Nursing2021*. 2010;40(11):46-47. doi:10.1097/01.NURSE.0000389025.10889.c3

16. *An Organisation with a Memory: Report of an Expert Group on Learning from Adverse Events in the NHS*. Department of Health; 2000.

17. Oikonomou E, Carthey J, Macrae C, Vincent C. Patient safety regulation in the NHS: mapping the regulatory landscape of healthcare. *BMJ Open*. 2019;9(7):e028663. doi:10.1136/bmjopen-2018-028663

18. Francis R. *Report of the Mid Staffordshire NHS Foundation Trust Public Enquiry: Executive Summary*. Stationery Office (TSO); 2013.

19. NHS England and NHS Improvement. *The NHS Patient Safety Strategy*.; 2019:1-84. Accessed March 15, 2021. https://www.england.nhs.uk/wp-content/uploads/2020/08/190708_Patient_Safety_Strategy_for_website_v4.pdf

20. Blümel M, Spranger A, Achstetter K, Maresso A, Busse R. *Germany: Health System Review*. World Health Organization. Regional Office for Europe; 2020; 22(6): pp.i–273. Accessed July 08, 2021. https://apps.who.int/iris/handle/10665/341674

21. Busse R, Nimptsch U, Mansky T. Measuring, Monitoring, And Managing Quality In Germany's Hospitals | Health Affairs. Health Aff (Millwood). 2009;(28). doi: https://doi.org/10.1377/hlthaff.28.2.w294

22. Aktionsbündnis Patientensicherheit. Accessed March 15, 2021. https://www.aps-ev.de/recommendations-in-english/

23. Pross C, Geissler A, Busse R. Measuring, Reporting, and Rewarding Quality of Care in 5 Nations: 5 Policy Levers to Enhance Hospital Quality Accountability. *Milbank Q*. 2017;95(1):136-183. doi:10.1111/1468-0009.12248

24. Rafter N, Hickey A, Condell S, et al. Adverse events in healthcare: learning from mistakes. *QJM Int J Med*. 2015;108(4):273-277. doi:10.1093/qjmed/hcu145

25. Hauck K, Zhao X. How Dangerous is a Day in Hospital? A Model of Adverse Events and Length of Stay for Medical Inpatients. *Med Care*. 2011;49(12):1068-1075.

26. Adamuz J, Juvé-Udina M-E, González-Samartino M, et al. Care complexity individual factors associated with adverse events and in-hospital mortality. *PLOS ONE*. 2020;15(7):e0236370. doi:10.1371/journal.pone.0236370

27. Tanke MAC, Feyman Y, Bernal-Delgado E, et al. A challenge to all. A primer on inter-country differences of high-need, high-cost patients. *PLOS ONE*. 2019;14(6):e0217353. doi:10.1371/journal.pone.0217353

28. Long P, Abrams M, Milstein A, Anderson G, Lewis Apton K, Lund Dahlberg M, and Whicher D. *Effective Care for High-Need Patients: Opportunities for Improving Outcomes, Value, and Health*. National Academy of Medicine; 2017:1-213. Accessed March 15, 2021. https://nam.edu/wp-content/uploads/2017/06/Effective-Care-for-High-Need-Patients.pdf

29. Joynt K, Figueroa JF, Beaulieu N, Wild R, Orav E, Jha AK. Segmenting high-cost Medicare patients into potentially actionable cohorts. *Healthcare*. 2017;5(1-2). doi:10.1016/j.hjdsi.2016.11.002

30. Research Data Centres of the Federal Statistical Office and Statistical Offices of the Federal States, [Diagnosis-Related Groups Statistic], survey year [2018], own calculations. DOI: 10.21242/23141.2018.00.00.1.2.0

31. Bottle A, and Aylin P. Application of AHRQ patient safety indicators to English hospital data. *BMJ Quality and Safety*. 2009; 18(303-308).

32. Soong J, Poots AJ, Scott S, Donald K, Bell D. Developing and validating a risk prediction model for acute care based on frailty syndromes. *BMJ Open*. 2015;5(10):e008457. doi:10.1136/bmjopen-2015-008457

33. Soong J, Poots A, Scott S, et al. Quantifying the prevalence of frailty in English hospitals. *BMJ Open*. 2015;5(10). doi:10.1136/bmjopen-2015-008456

34. Austin SR, Wong Y-N, Uzzo RG, Beck JR, Egleston BL. Why summary comorbidity measures such as the Charlson Comorbidity Index and Elixhauser score work. *Med Care*. 2015;53(9):e65-e72. doi:10.1097/MLR.0b013e318297429c

35. Austin PC. An Introduction to Propensity Score Methods for Reducing the Effects of Confounding in Observational Studies. *Multivar Behav Res*. 2011;46(3):399-424. doi:10.1080/00273171.2011.568786

36. Global action on patient safety. *World Health Assembly*. 2019; 5.

37. AOK-Gesundheitsnavigator: Informationen für Krankenhäuser. AOK Gesundheitspartner. Accessed March 15, 2021. /gp/verwaltung/versorgungsqualitaet/gesundheitsnavigator-krankenhaus

38. de Hoon SEM, Hek K, van Dijk L, Verheij RA. Adverse events recording in electronic health record systems in primary care. *BMC Med Inform Decis Mak*. 2017;17(1):163. doi:10.1186/s12911-017-0565-7

39. Friebel R, Hauck K, Aylin P. Centralisation of acute stroke services in London: Impact evaluation using two treatment groups. *Health Econ*. 2018;27(4):722-732. doi:https://doi.org/10.1002/hec.3630

40. Baier N, Sax L-M, Sundmacher L. Trends and regional variation in rates of orthopaedic surgery in Germany: the impact of competition. *Eur J Health Econ*. 2019;20(1):163-174. doi:10.1007/s10198-018-0990-2

41. House of Commons Health Committee. Patient Safety. 2009; Vol(1). https://publications.parliament.uk/pa/cm200809/cmselect/cmhealth/151/151i.pdf (accessed on June 23rd, 2021)

42. Strausberg J. International prevalence of adverse drug events in hospitals: an analysis of routine data from England, Germany, and the USA. *BMC Health Services Research*. 2014;14(125). https://doi.org/10.1186/1472-6963-14-125

43. Feng C, Le D, McCoy AB. Using Electronic Health Records to Identify Adverse Drug Events in Ambulatory Care: A Systematic Review. *Appl Clin Inform*. 2019;10(1):123-128. doi:10.1055/s-0039-1677738

44. Wammes JJG, Wees PJ van der, Tanke MAC, Westert GP, Jeurissen PPT. Systematic review of high-cost patients' characteristics and healthcare utilisation. *BMJ Open*. 2018;8(9):e023113. doi:10.1136/bmjopen-2018-023113

45. Friebel R, Hauck K, Aylin P, Steventon A. National trends in emergency readmission rates: a longitudinal analysis of administrative data for England between 2006 and 2016. *BMJ Open*. 2018;8(3):e020325. doi:10.1136/bmjopen-2017-020325

46. Fink A, Yano EM, Brook RH. The Condition of the Literature on Differences in Hospital Mortality. *Med Care*. 1989;27(4):315-336.

47. Lingsma HF, Bottle A, Middleton S, Kievit J, Steyerberg EW, Marang-van de Mheen PJ. Evaluation of hospital outcomes: the relation between length-of-stay, readmission, and mortality in a large international administrative database. *BMC Health Serv Res*. 2018;18(1):116. doi:10.1186/s12913-018-2916-1

48. Krumholz HM. Post-Hospital Syndrome – A Condition of Generalized Risk. *N Engl J Med*. 2013;368(2):100-102. doi:10.1056/NEJMp1212324

49. Friebel R, Dharmarajan K, Krumholz HM, Steventon A. Reductions in Readmission Rates Are Associated With Modest Improvements in Patient-reported Health Gains Following

Hip and Knee Replacement in England. *Med Care*. 2017;55(9):834-840. doi:10.1097/MLR.0000000000000779

50. Newgard CD, Fleischman R, Choo E, Ma OJ, Hedges JR, McConnell KJ. Validation of length of hospital stay as a surrogate measure for injury severity and resource use among injury survivors. *Acad Emerg Med Off J Soc Acad Emerg Med*. 2010;17(2):142-150. doi:10.1111/j.1553-2712.2009.00647.x

51. Kaier K, Mutters NT, Frank U. Bed occupancy rates and hospital-acquired infections—should beds be kept empty? *Clin Microbiol Infect*. 2012;18(10):941-945. doi:10.1111/j.1469-0691.2012.03956.x

52. Friebel R, Juarez RM. Spill Over Effects of Inpatient Bed Capacity on Accident and Emergency Performance in England. *Health Policy Amst Neth*. 2020;124(11):1182-1191. doi:10.1016/j.healthpol.2020.07.008

53. Friebel R, Fisher R, Deeny SR, Gardner T, Molloy A, Steventon A. The implications of high bed occupancy rates on readmission rates in England: A longitudinal study. *Health Policy*. 2019;123(8):765-772. doi:10.1016/j.healthpol.2019.06.006

54. Kings Fund. The health care workforce in England: make or break? :14.

55. Aiken LH, Sermeus W, Heede KV den, et al. Patient safety, satisfaction, and quality of hospital care: cross sectional surveys of nurses and patients in 12 countries in Europe and the United States. *BMJ*. 2012;344:e1717. doi:10.1136/bmj.e1717

56. OECD. *Health at a Glance 2019: OECD Indicators*. OECD; 2019. doi:10.1787/4dd50c09-en

57. Kuklik N, Stausberg J, Jöckel K-H. Adverse drug events in German hospital routine data: A validation of International Classification of Diseases, 10th revision (ICD-10) diagnostic codes. *PloS One*. 2017;12(11):e0187510. doi:10.1371/journal.pone.0187510

Table 1. Descriptive: patient characteristics and outcomes for Germany and England in 2018.

	England		Germany	
	Adverse event	**Non adverse event**	**Adverse event**	**Non adverse event**
	N=415,983	**N=7,329,639**	**N=570,088**	**N=16,927,961**
Patient characteristics				
Sex (=1 Male) (%)	48.61%	40.41%	49.18%	50.47%
Age (mean, sd)	72.37 (16.88)	56.05 (22.20)	68.38 (18.13)	56.82 (25.82)
Charlson Comorbidity Index =0 (%)	18.83%	52.00%	23.66%	51.50%
Charlson Comorbidity Index =1 (%)	21.34%	20.52%	15.60%	15.89%
Charlson Comorbidity Index =2 (%)	20.19%	11.83%	16.71%	11.87%
Charlson Comorbidity Index =3 (%)	13.78%	6.23%	13.30%	7.42%
Charlson Comorbidity Index =4 (%)	8.88%	3.41%	9.62%	4.55%
Charlson Comorbidity Index =5 (%)	4.79%	1.66%	6.22%	2.61%
Charlson Comorbidity Index =6+ (%)	12.19%	4.36%	14.88%	6.15%
Emergency (%)	89.33%	68.83%	58.00%	45.46%
Number of procedures (mean, sd)	4.35 (6.40)	2.06 (3.09)	8.26 (11.18)	3.52 (4.19)
Weekdays discharge (=1 Monday to Friday) (%)	82.12%	78.66%	87.58%	82.98%
Winter discharge (=1 November to February) (%)	34.28%	32.57%	30.14%	32.54%
High Need patient definitions				
High Need patient (NAM) (%)	86.25%	54.05%	77.43%	51.33%
Non-elderly disabled (%)	*0.75%*	*0.42%*	*0.75%*	*0.33%*
Multi-chronic (%)	*63.80%*	*42.25%*	*58.78%*	*41.21%*
Major complex chronic (%)	*55.13%*	*26.74%*	*48.01%*	*25.23%*
Advance illness (%)	*10.47%*	*1.60%*	*1.51%*	*0.43%*
Frail elderly (%)	*2.61%*	*0.38%*	*5.12%*	*0.80%*
High Need patient (Charlson>3) (%)	25.87%	9.42%	30.72%	13.32%
Outcomes				
In-hospital mortality (%)	3.25%	0.96%	10.58%	2.13%
Length of stay (mean, sd)	11.13 (16.02)	2.43 (6.67)	14.95 (17.34)	5.69 (6.90)

Table 2. Adverse events by high need patients

	Adverse event		*Infections*		*Adverse Drug Reaction*		*Pres Ulcer*	
	England	**Germany**	**England**	**Germany**	**England**	**Germany**	**England**	**Germany**
High Need NAM	**8.30%**	**4.84%**	4.45%	2.06%	2.37%	2.49%	2.25%	0.45%
Non-elderly disabled	**9.09%**	**6.98%**	6.30%	5.27%	2.33%	1.69%	1.15%	0.31%
Multi-chronic	**7.89%**	**4.58%**	4.16%	1.91%	2.46%	2.47%	2.00%	0.36%
Major complex chronic	**10.47%**	**6.02%**	5.89%	2.75%	2.47%	2.84%	3.17%	0.66%
Advance illness	**27.11%**	**10.50%**	17.27%	5.87%	3.99%	3.54%	9.83%	1.68%
Frail elderly	**28.19%**	**17.75%**	11.73%	4.79%	2.76%	3.41%	18.27%	11.17%
High Need Charlson	**13.48%**	**7.21%**	7.31%	3.66%	3.97%	3.17%	3.53%	0.68%

Table 3. Causal impact of adverse events on patient outcomes

	Adverse Events		Infections		Adv. Drug reactions		Pres Ulcer	
	England	**Germany**	**England**	**Germany**	**England**	**Germany**	**England**	**Germany**
Panel A: All sample with DRG								
ATT on dead	0.007***	0.037***	0.018***	0.097***	0.007***	0.014***	0.002	0.061***
	(0.002)	(0.001)	(0.002)	(0.002)	(0.001)	(0.001)	(0.002)	(0.003)
ATT on LoS	6.655***	3.606***	11.366***	6.113***	1.454***	1.349***	12.374***	4.563***
	(0.088)	(0.061)	(0.124)	(0.090)	(0.095)	(0.067)	(0.181)	(0.143)
Panel B: All sample with high-need subgroup								
ATT on dead	0.002	0.064***	0.014***	0.154***	0.008*	0.009	-0.007	0.083***
	(0.005)	(0.006)	(0.005)	(0.006)	(0.004)	(0.006)	(0.006)	(0.005)
ATT on LoS	7.466***	7.417***	13.050***	14.708***	1.555***	2.167***	14.134***	8.741***
	(0.193)	(0.193)	(0.191)	(0.206)	(0.205)	(0.221)	(0.247)	(0.194)
Panel C: All sample with ICD chapter								
ATT on dead	0.008***	0.070***	0.020***	0.165***	0.007***	0.006***	0.004	0.106***
	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.003)	(0.004)
ATT on LoS	7.596***	7.507***	13.262***	14.441***	1.650***	2.320***	14.038***	9.545***
	(0.135)	(0.106)	(0.161)	(0.130)	(0.141)	(0.120)	(0.219)	(0.161)
N (dead)	7,745,622	17,498,049	7,745,622	17,498,049	7,745,622	17,498,049	7,745,622	17,498,049
N (LoS)	5,899,764	17,498,049	5,899,764	17,498,049	5,899,764	17,498,049	5,899,764	17,498,049
Year	2018	2018	2018	2018	2018	2018	2018	2018

*Notes: Columns report the Average Treatment Effect on the Treated (ATT) and the standard errors. Significance: *** p<0.01, ** p<0.05, * p<0.1. Propensity score matching on age, gender, charlson index and emergency admission. Balance test fulfilled for all models in England and Germany. The sample size N differs between outcome variables, given that length of stay only applies to patients who have been admitted on or after January 1st, 2018, and discharged before December 31st, 2018. For estimating the impact on in-hospital mortality we included all patients irrespective of day of admission or discharge.*

Figure legends

Figure 1. Proportion of adverse events in Germany and England in 2018

Figure 2. Predictors of adverse events