Journal of Hospital Infection 101 (2019) 313–319

Available online at www.sciencedirect.com

Journal of Hospital Infection

journal homepage: www.elsevier.com/locate/jhin

Identifying hospital-acquired infections using retrospective record review from the Irish National Adverse Events Study (INAES) and European point prevalence survey case definitions

N. Rafter [a,*], R. Finn [b], K. Burns [c], S. Condell [d], R.M. Conroy [e], A. Hickey [f], P. O'Connor [g], D. Vaughan [h], G. Walsh [i], D.J. Williams [j]

[a] *Department of Epidemiology & Public Health Medicine, Division of Population Health Sciences, Royal College of Surgeons in Ireland (RCSI), Dublin, Ireland*
[b] *Royal College of Surgeons in Ireland (RCSI), Dublin, Ireland*
[c] *Department of Clinical Microbiology, RCSI and Beaumont Hospital, Health Protection Surveillance Centre, Dublin, Ireland*
[d] *Clinical Effectiveness Unit, National Patient Safety Office, Department of Health, Dublin, Ireland*
[e] *Division of Population Health Sciences, RCSI, Ireland*
[f] *Department of Psychology, Division of Population Health Sciences, RCSI, Ireland*
[g] *Discipline of General Practice, National University of Ireland, Galway, Ireland*
[h] *Department of Quality and Safety, Children's Hospital Group, Dublin, Ireland*
[i] *Royal College of Physicians of Ireland, Dublin, Ireland*
[j] *Department of Geriatric & Stroke Medicine, RCSI and Beaumont Hospital, Dublin, Ireland*

ARTICLE INFO

Article history:
Received 22 October 2018
Accepted 19 December 2018
Available online 24 December 2018

Keywords:
Adverse events
Epidemiology and detection
Chart review methodologies
Hospital medicine
Infection control

SUMMARY

Background: Point prevalence surveys (PPSs) collect data on hospital-acquired infections (HAIs) at one point in time but do not provide information on incidence over the entire admission or impact on patients or healthcare resources. Retrospective record review examines the entire admission to determine adverse event prevalence, incidence, preventability, physical impairment and additional length of stay.

Aim: To establish whether European HAI surveillance definitions can be applied to the Irish National Adverse Events Study (INAES) retrospective record review data to determine HAI burden.

Methods: In the INAES, 1574 admissions were reviewed using a two-stage methodology and 247 adverse events were found. These were examined against European HAI case definitions to determine whether the event was an HAI. Results were compared with the 2011/12 European PPS data for Ireland.

Findings: The prevalence of HAI adverse events in INAES was 4.4% (95% confidence interval (CI) 3.1–6.1%) with an incidence of 3.8 (95% CI 2.5–5.2) HAI adverse events per 100 admissions. The PPS HAI prevalence for Ireland was 5.2%. HAI types and micro-organisms were similar in INAES and the PPS. Approximately three-quarters of INAES HAI adverse events were preventable, 7% caused permanent impairment and 7% contributed to death.

* Corresponding author. Address: Department of Epidemiology & Public Health Medicine, Division of Population Health Sciences, Royal College of Surgeons in Ireland (RCSI), 123 St Stephens Green, Dublin 2, Ireland, Tel.: +353 402 5197.
E-mail address: natasharafter@rcsi.com (N. Rafter).

https://doi.org/10.1016/j.jhin.2018.12.011

A mean of 10 additional bed days were attributed to HAI adverse events, equivalent to €9400 per event.

Conclusion: Retrospective record review is an accurate source of information on HAI incidence, preventability and impact that complements PPS prevalence rates. HAI adverse events result in higher costs to the healthcare system than other adverse events.

Introduction

Hospital acquired infections (HAIs) result in prolonged hospitalization, readmission, antimicrobial resistance plus healthcare and societal costs [1,2]. Improved surveillance is a key objective of the WHO Global Action Plan on Antimicrobial Resistance in order to demonstrate changes in HAI patterns and evaluate intervention effectiveness [3,4]. This will involve establishing accurate baseline data incorporating a range of methodologies to ensure that HAI occurrences and their consequences are well characterized and can be monitored for change.

Most national-level HAI data come from point prevalence surveys (PPSs) and targeted incidence surveillance systems (e.g., notifiable diseases, *Clostridium difficile* surveillance) [5,6]. The first European PPS in acute hospitals, conducted by the European Centre for Disease Prevention and Control (ECDC) across 33 countries in 2011/12, reported a 6% HAI prevalence for Europe and 5.2% for Ireland [7,8].

A PPS captures prevalence at one point in time, therefore excluding HAIs occurring at other times and underestimating the total burden [9]. Repeated surveys provide important trend data on HAI types, antimicrobial resistance and treatment patterns. They can be used to assess compliance with guidelines, monitor effectiveness of infection control programmes, identify changes in antimicrobial use and guide future priority setting [10–12]. Limitations include the need to derive incidence; patient outcomes and resource use cannot be determined (due to the absence of data after the survey date); and the lack of preventability assessment [1,11,13]. Retrospective record review using the Harvard Medical Practice Study (HMPS) methodology could help address these gaps as it allows for the collection and analysis of longitudinal data encompassing the entire admission and readmissions with in-depth review of each adverse event [14,15]. However, standard retrospective record review for adverse events does not incorporate HAI surveillance definitions and only a handful of studies have reported on HAIs [16–19]. Therefore, this study aimed to establish whether adding European HAI surveillance definitions to retrospective record review data from the Irish National Adverse Events Study (INAES) could determine HAI incidence, preventability and impact and complement ECDC PPS results [14,15].

Methods

The INAES was a two-stage retrospective record review study [15]. All 30 acute public hospitals in the Republic of Ireland were invited to participate. Of the 18 hospitals that agreed to participate, one large and one small were randomly selected from each of the four health regions. A random sample of 300–400 'index' admissions was generated at each site using the hospital's local electronic discharge database. The sampling frame included all inpatient admissions for patients aged at least 18 years in 2009 who had a minimum stay in hospital of 24 h (or died within 24 h), excluding admissions with obstetric or psychiatric principal diagnoses. Admissions were stratified by whether or not a surgical procedure was likely to have been performed based on anaesthetic procedure coding [15].

Stage-one: Nurses screened medical records of the first 200 eligible admissions (plus 12 months before and after) at each participating hospital for 18 adverse event triggers.

Stage-two: Physicians reviewed triggered admissions to determine adverse event presence (defined as 'an unintended injury or complication resulting in disability at the time of discharge, prolonged hospital stay or death and that was caused by healthcare management rather than by the underlying disease process') [14,15]. Physician reviewers wrote clinical summaries of each admission and evaluated adverse events for: physical impairment due to the adverse event on discharge (six-point scale: 1 = no impairment, 6 = death); preventability (six-point scale: 1 = no evidence for preventability, 6 = certain evidence); and additional length-of-stay attributed to the event [15].

INAES received ethics approval from the Royal College of Surgeons in Ireland (REC815) and the Royal College of Physicians of Ireland (RCPI RECSAF 04).

HAI review

In INAES, 1574 eligible admissions were reviewed, 45% were triggered and 703 proceeded to stage-two review by physicians who identified 247 adverse events in 211 admissions [15]. The clinical summaries of these 247 events were analysed for HAIs by two authors (R.F. and N.R.) trained in the ECDC PPS methodology. Discrepancies were resolved with a consultant clinical microbiologist (K.B.), national coordinator for Ireland in ECDC PPS 2011/2012 and 2017.

> An HAI adverse event was defined as 'an adverse event due to an infection acquired during, or as a consequence of, an acute care hospital stay with onset of symptoms on day three or later of the index admission
> OR the patient was readmitted with infection within two days of discharge from the index hospital
> OR the patient was readmitted within 30 days of the operation with a surgical site infection (or with a deep or organ/space SSI that developed within a year of surgery that involved an implant)
> OR the patient was readmitted with *Clostridium difficile* infection within 28 days after a previous discharge from the index hospital
> OR an invasive device was placed on day one or day two, resulting in an HAI before day three' [7].

Each HAI adverse event was classified using the ECDC PPS 2011/12 case definitions (protocol version 4.3) [7]. Where information was available, the causative micro-organism(s) and

antimicrobial resistance markers were noted. The case definitions were adhered to as much as possible, within the context of the data available in the INAES dataset.

Analysis

HAI adverse event period prevalence was calculated as the proportion of admissions associated with one or more HAI adverse events out of all admissions. HAI incidence density was the number of HAI adverse events occurring per 100 admissions excluding events occurring prior to the index admission (to avoid double counting) [15]. Logistic regression was used to compare HAI adverse event prevalence between subgroups. HAI adverse event analyses were weighted to reflect the sampling criteria (i.e. ratio of surgery and non-surgery admissions in each hospital's eligible study population). Confidence intervals (CIs) for binary variables were modelled using logistic regression; CIs for incidence were calculated using Poisson regression with robust variance estimation; *P*-values were derived from logistic regression, unless otherwise noted.

To establish the baseline cost of HAI adverse events in adult inpatients in 2009, the product of (1) number of HAI adverse events (= incidence density of HAI adverse events × number of adult inpatient admissions to acute Irish public hospitals in 2009 ($N = 339,844$ [20])); and (2) average cost of a HAI adverse event (= mean number of added bed days attributed to HAI adverse events × 2009 inpatient bed cost (€909 per day, Healthcare Pricing Office)) was estimated [21]. The rationale for using 2009 costs was that this is the year from which the data were collected.

Analyses were undertaken using Stata release 13.1. INAES results were compared with the ECDC PPS 2011/12 results for Ireland, as the closest reference dataset [8,22].

Results

Of the 247 adverse events, 78 were HAIs (in 73 admissions) representing a weighted proportion of 32.5% (95% CI 26.3–39.4%). The weighted prevalence of HAI adverse events was 4.4% (95% CI 3.1–6.1%, Table I). The PPS prevalence of HAIs for Ireland was 5.2% (95% CI 4.7–5.6%) and 5.0% if patients aged

Table I
Comparison of Irish National Adverse Events Study and ECDC point prevalence survey 2011/12 Ireland results

Variable	INAES HAI adverse events[a]	ECDC PPS 2011/12 Ireland HAIs [22]
Prevalence (95% CI)	4.4% (3.1–6.1%)	5.2% (4.7–5.6%) (5.0% if patients aged ≤5 years of age and acute psychiatric patients excluded)
Incidence (95% CI)	3.8 HAI adverse events per 100 admissions (95% CI 2.5–5.2)	No data
Prevalence in males (95% CI)	5.0% (2.8–7.2%)	5.8%
Prevalence in females (95% CI)	3.9% (2.4–5.4%)	4.6%
Prevalence if surgery performed in admission (95% CI)	6.7% (5.2–8.2%)	(surgery) 11.5% (9.9–13.4%) (other operative procedure) 5.9% (3.9–9.0%)
Prevalence if no surgery performed in admission (95% CI)	3.6% (2.0–5.2%)	4.1% (3.6–4.5%)
Prevalence surgical consultant	(discharge) 5.3% (3.8–6.8%)	(admitting) 8.1% (7.1–9.3%)
Prevalence medical consultant	(discharge) 3.8% (1.9–5.6%)	(admitting) 5.1% (4.5–5.8%)
Prevalence in ICU (95% CI)	14.6% (5.8–23.4%) (admission included ICU stay)	16.5% (13.2–20.3%) (on augmented care unit)
Prevalence if no ICU stay (95% CI)	3.6% (2.4–4.8%)	7.3% (5.5–9.7%) (mixed specialty ward) 6.7% (5.7–7.9%) (surgical ward) 4.8% (4.1–5.6%) (medical ward)
% Preventable (95% CI)	74.0% (50.7–88.7%)	No data
% Resulting in no physical impact on discharge (95% CI)	22.0% (15.5–30.4%)	No data
% Resulting in minimal impairment or recovery in 1 month (95% CI)	31.4% (22.1–42.6%)	No data
% Resulting in moderate impairment, recovery in 1–6 months (95% CI)	23.7% (15.2–35.0%)	No data
% Resulting in moderate impairment, recovery in 6–12 months (95% CI)	2.6% (0.6–10.0%)	No data
% Resulting in permanent disability (95% CI)	6.8% (1.6–25.3%)	No data
% Contributing to death (95% CI)	6.7% (2.2–18.2%)	No data
Median duration of admission with HAI (interquartile range)	18 days (7,31)	No data
Median duration of admission without HAI (interquartile range)	4 days (2,8)	No data
Mean additional bed days due to HAI (95% CI)	10.3 (6.8–15.7)	No data

CI, confidence interval; HAI, hospital-acquired infection; ICU, intensive care unit.
[a] Point estimates and CIs were weighted to account for the sampling frame.

Table II
Distribution of type of hospital-acquired infection in Irish National Adverse Events Study and ECDC point prevalence survey 2011/12 Ireland

INAES[a]		ECDC Ireland [22]	
HAI type	%	HAI type	%
Pneumonia/lower respiratory tract	31	Pneumonia/lower respiratory tract	19
Surgical site	27	Surgical site	18
Gastrointestinal	19	Urinary tract	15
Bloodstream, including catheter-related bloodstream infections	15	Bloodstream, including catheter-related bloodstream infections	13
Skin/soft tissue	3	Gastrointestinal	10
Urinary tract	2	Systemic	8
Catheter-related infection, no positive blood culture	2	Eye, ear, nose, mouth	5
Systemic	1	Bone/joint	4
Central nervous system	1	Skin/soft tissue	3

HAI, hospital-acquired infection; INAES, Irish National Adverse Events Study.
[a] Point estimates were weighted to account for the sampling frame.

≤15 years of age and acute psychiatric patients were excluded [22]. The INAES weighted incidence density was 3.8 HAI adverse events (95% CI 2.5–5.2) for every 100 admissions. In the INAES study, 18% of the HAI adverse events were related to previous admissions and this was 24% in the PPS for Ireland [22].

The majority (77.1%) of INAES HAI adverse events had a recovery time of ≤6 months. However, in 6.7% the HAI may have contributed to, or resulted in, death (Table I). Almost three-quarters of HAI adverse events were deemed preventable. INAES admissions with HAI adverse events were longer (median 18 days) than admissions without (4 days, $P < 0.001$, Wilcoxon Mann–Whitney test). The mean number of additional hospital days attributed to HAI adverse events was 10.3, resulting in an additional cost of €9400 for each HAI adverse event, which when extrapolated nationally equates to a €121-million annual cost to the Irish healthcare system. The PPS data for Ireland found increasing prevalence of HAIs with increasing age (age up to 44 years prevalence 3.4%, age 45 and above prevalence 6.0%) [22]. The INAES determined that the mean age of patients with a HAI adverse event was 64.6 years vs 55.8 without ($P < 0.001$, *t*-test) and with each 10-year age increment there was a 26% increase in HAI adverse event prevalence (odds ratio (OR) 1.26, 95% CI 1.14–1.39). There was no difference in HAI adverse event prevalence between male and female admissions ($P = 0.401$) or between elective and emergency admissions ($P = 0.897$) in INAES. However, the PPS found a higher prevalence of HAIs in males (5.8%) compared with females (4.6%, $P = 0.008$) [22].

The INAES prevalence of HAI adverse events was higher in admissions which included treatment in an intensive care environment than in those without (14.6% vs 3.6%, respectively, $P = 0.001$, Table I). In the PPS, HAI prevalence in augmented care units was 16.5% compared with 7.3% in mixed specialty wards and 6.7% in surgical wards [22]. INAES admissions where surgery was likely to have been performed had a higher HAI adverse event prevalence (6.7%) compared with non-surgery admissions (3.6%, $P = 0.03$). However, when the analysis was performed using the specialty of the consultant associated with the principal diagnosis, no significant difference was observed (surgical 5.3%, medical 3.8%, $P = 0.176$). In the PPS data the prevalence of HAIs was 11.5% in patients who had undergone surgery (defined as involving an incision and taking place in an operating room) since admission, 5.9% for other operative procedures and 4.1% if no surgery had taken place [22].

HAI types were similar in both INAES and the PPS data – the top two in both were surgical site infections and pneumonia/lower respiratory tract (Table II). Microbiology results were available for 59.0% (46/78) of HAI adverse events in INAES and 52.1% in the PPS [22].

In the PPS *Escherichia coli* was the most commonly identified pathogen, whereas it was third in INAES. The most common organisms in INAES were *Staphylococcus aureus, Clostridium difficile,* and *E. coli* (Table III) [22]. In INAES antimicrobial susceptibility information was documented in 36.7% (11/30) of isolates where resistance data was required by the ECDC PPS protocol, whereas in the PPS this was over 90% for Ireland [8]. Over half (6/11) of *S. aureus* isolates were methicillin-resistant *S. aureus (*MRSA) and 75% (3/4) of *Enterococcus* spp. were vancomycin resistant.

Discussion

This is the first time the HMPS retrospective record review methodology has been adapted to incorporate international HAI definitions [14]. This is also the first study to calculate the national incidence, preventability and physical impact of HAI adverse events in Ireland and estimate their annual cost. A marked increase was found in length of stay for HAI adverse events compared to other adverse events – our previously published INAES main analysis found that adverse events resulted in a mean of six additional bed days, whereas for HAI adverse events this is over 10 [15]. Therefore, while HAI adverse events represent 32.5% of the burden in numbers, they contribute more than 60% of the cost. This is consistent with a Dutch national adverse events study where HAI adverse events had the longest additional length of stay and highest costs when compared to other types of adverse events [23].

The INAES and PPS analyses provide similar results although the study populations differ: the PPS included neonatal, paediatric, maternity and psychiatric populations; all excluded from INAES. In addition, the INAES HAI adverse event

Table III
Distribution of microorganisms in the Irish National Adverse Events Study and ECDC point prevalence survey 2011/12 Ireland

INAES[a]		ECDC PPS 2011/12 Ireland [22]	
Micro-organism	%	Micro-organism	%
Staphylococcus aureus	16	*Escherichia coli*	20
Clostridium difficile	16	*Staphylococcus aureus*	15
Escherichia coli	11	*Enterococcus* spp.	11
Pseudomonas spp.	11	*Clostridium difficile*	9
Norovirus	9	*Candida* spp.	7
Enterococcus spp.	6	*Pseudomonas aeruginosa*	4
Gram-negative bacilli, non-Enterobacteriaceae, not specified	4	Other	19
Coagulase-negative staphylococci	4		
Klebsiella spp.	4		
Proteus spp.	4		

INAES, Irish National Adverse Events Study; PPS, point prevalence survey.
[a] Point estimates were weighted to account for the sampling frame.

prevalence does not capture HAIs that do not satisfy the adverse event definition (i.e. resulting in prolonged hospitalization or disability at discharge or death) or those originating in hospitals other than the index hospital [15]. Hence, the actual prevalence of all HAIs would be expected that to be higher than 4.4%.

In INAES there were few urinary tract infection (UTI) adverse events, whereas these were prominent in the PPS. Many of the INAES admissions' clinical summaries did include mention of a UTI, but if they were not adverse events then they were not captured in the HAI adverse event analysis. This is probably because a large proportion of UTIs are managed within an admission without substantial morbidity [2]. This in turn impacts on the causative pathogens: in the PPS *E. coli* (the most frequent UTI pathogen) was the most commonly identified pathogen, whereas it was third in INAES.

INAES provides an overall estimate of the 2009 HAI cost to the healthcare system (€121 million). This is very similar to the Irish Health Service Executive estimate of €118 million which was not based on Irish data on impact but drew on a number of sources for mortality, prolonged hospitalization and cost information [24–26]. Both figures are underestimates as bed days only account for 30–40% of inpatient costs which in turn represent less than half of all healthcare costs [25,27–29].

The major strengths of the INAES HAI results are that the entire admission plus readmissions are reviewed using an internationally standardized methodology with the ability to estimate incidence, physical impact, preventability and cost. Therefore, the INAES provides additional information on incidence, impact and preventability not supplied by PPS methods.

A further strength is that the ECDC PPS 2011/12 protocol and case definitions were employed by trained reviewers; thus allowing comparison with international prevalence data. The use of 2009 admissions establishes a baseline which is able to be compared with the ECDC 2011/12 PPS and can be used to track progress in infection control as direct comparisons are now possible with the ECDC 2017 PPS and INAES-2 (currently underway reviewing 2015 admissions).

INAES is an adverse event, not an HAI surveillance, study. The focus of INAES was on identifying adverse events; thus HAIs not satisfying the adverse event definition were not included in the analysis. There was no separate category for HAIs in the stage-two review. Therefore, information on HAI diagnoses, microorganisms and sensitivities, surgical prophylaxis, device insertion, care bundles, hygiene patterns, skin issues and antimicrobial treatment were not collected in dedicated fields. Despite this, the level of absent micro-organism data was lower in INAES compared with the PPS but resistance information was poorly documented in INAES [8].

As with any retrospective record review, data collection was limited by the healthcare record documentation and for the INAES HAI review this was further restricted to information in the reviewers' clinical summaries [15]. As a result of this, INAES HAI reviewers were not always able to strictly apply some of the ECDC case definitions. For example, the 2011/12 ECDC PPS case definition for pneumonia requires two chest X-rays for patients with underlying cardiac/pulmonary disease [7]. In INAES, if a prior chest X-ray was likely to have been taken (e.g., presentation with chest symptoms) and a diagnosis of hospital-acquired pneumonia was documented, then the case definition was assumed to be satisfied.

Work is underway to adapt the INAES data collection instrument into an audit tool to make it accessible to frontline clinical personnel, infection control departments and hospital quality and risk staff. As part of this, a separate HAI category consistent with ECDC definitions will be incorporated and compulsory fields for HAI assessment. It is hoped that this methodology, as well as providing national data, will be used for ongoing local HAI monitoring. Furthermore, the collection of clinical summaries allows a depth of data to draw upon which could also be adapted to elucidate hospital and human factors influencing HAI occurrence.

Retrospective record review provides additional information on the incidence, impact and preventability of HAI adverse events not provided by current surveillance methods. It has the potential to be used to generate both national- and local-level HAI data in the future. This 2009 INAES HAI analysis expands on the 2011/12 HAI surveillance PPS data and together they give a more comprehensive baseline impression of HAIs in acute hospitals. Both methodologies are being repeated incorporating the same definitions and will therefore further contribute to the longitudinal information needed to monitor HAI trends and the effectiveness of control measures.

Acknowledgements

The authors gratefully acknowledge the support and assistance provided by the eight participating hospital sites, especially their managerial and administrative staff who facilitated the environment and chart access for the study. We are extremely grateful for the hard work of our nurse and physician reviewers. We thank Professor Ross Baker, Virginia Flintoft and Dr Anne Matlow at the University of Toronto for their training and advice. Thanks also go to Dr Barry White, Dr Philip Crowley, Dr Ann Coughlan, Sarah Kennedy, Dr Lucia Prihodova, our surgeon advisor, and the members of the INAES advisory group. We thank the 2017 Ireland PPS team for allowing us to attend the ECDC PPS training.

Conflict of interest statement

R. Conroy, A. Hickey, D. Williams and N. Rafter report receiving a grant from the Health Research Board of Ireland and Health Service Executive within the Research Collaborative in Quality and Patient Safety (RCQPS/2013/1) and financial support from the Office of the Nursing and Midwifery Services Director, Health Service Executive during the conduct of the study. R. Finn reports support from Royal College of Surgeons in Ireland Research Summer School during the conduct of the study.

Funding sources

This work was supported by the Health Research Board of Ireland and Health Service Executive within the Research Collaborative in Quality and Patient Safety (RCQPS/2013/1), the Office of the Nursing and Midwifery Services Director of the Health Service Executive and the Royal College of Surgeons in Ireland Research Summer School.

References

[1] Cassini A, Plachouras D, Eckmanns T, Sin MA, Blank H-P, Ducomble T, et al. Burden of six healthcare-associated infections on European population health: estimating incidence-based disability-adjusted life years through a population prevalence-based modelling study. PLoS Med 2016;13(10):e1002150.

[2] World Health Organization. Report on the burden of endemic health care-associated infection worldwide. Clean care is safer care. A systematic review of the literature. Geneva, Switzerland: World Health Organization; 2011.

[3] World Health Organization. Global action plan on antimicrobial resistance. Geneva, Switzerland: World Health Organization; 2015.

[4] European Commission. A European one health action plan against antimicrobial resistance (AMR). European Commission; 2017.

[5] Health Protection Surveillance Centre. Notifiable diseases and their respective causative pathogens. Dublin, Ireland: Health Services Executive; 2018. Available from: http://www.hpsc.ie/notifiablediseases/listofnotifiablediseases/ [last accessed 15 January 2019].

[6] Health Protection Surveillance Centre. National enhanced surveillance of *Clostridium difficile* infection in Ireland, Quarter 2 2018. Dublin, Ireland: Health Protection Surveillance Centre; 2018. Available from: http://www.hpsc.ie/a-z/gastroenteric/clostridiumdifficile/cdifficiledataandreports/ [last accessed 15 January 2019].

[7] European Centre for Disease Prevention and Control. Point prevalence survey of healthcare-associated infections and antimicrobial use in European acute care hospitals - protocol version 4.3. Stockholm: ECDC; 2012.

[8] European Centre for Disease Prevention and Control. Point prevalence survey of healthcare-associated infections and antimicrobial use in European acute care hospitals. Stockholm: ECDC; 2013.

[9] Michel P, Quenon Q, de Sarasqueta A Scemama O. Comparison of three methods for estimating rates of adverse events and rates of preventable adverse events in acute care hospitals. Br Med J 2004;328:199—204.

[10] Skoog G, Struwe J, Cars O, Hanberger H, Odenholt J, Prag M, et al. Repeated nationwide point-prevalence surveys of antimicrobial use in Swedish hospitals: data for actions 2003-2010. Euro Surveill 2016;21(25):30264.

[11] Humphreys H, Smyth ETM. Prevalence surveys of healthcare-associated infections: what do they tell us, if anything? Clin Microbiol Infect 2006;12:2—4.

[12] Reilly J, Cairns S, Fleming S, Hewitt D, Lawder R, Robertson C, et al. Results from the second Scottish national prevalence survey: the changing epidemiology of healthcare-associated infection in Scotland. J Hosp Inf 2012;82:170—4.

[13] Magill S, Edwards J, Bamberg W, Beldavs Z, Dumyati G, Kainer M, et al. Multistate point-prevalence survey of health care-associated infections. New Engl J Med 2014;370:1198—208.

[14] Brennan TA, Leape LL, Laird NM, Hebert L, Localio AR, Lawthers AG, et al. Incidence of adverse events and negligence in hospitalized patients: results of the Harvard Medical Practice Study I. New Engl J Med 1991;324:370—6.

[15] Rafter N, Hickey A, Conroy RM, Condell S, O'Connor P, Vaughan D, et al. The Irish National Adverse Events Study (INAES): the frequency and nature of adverse events in Irish hospitals-a retrospective record review study. BMJ Qual Saf 2017;26:111—9.

[16] Aranaz-Andres JM, Aibar-Remon C, Limon-Ramirez R, Amarilla A, Restrepo FR, Urroz O, et al. Prevalence of adverse events in the hospitals of five Latin American countries: results of the 'Iberoamerican study of adverse events' (IBEAS). BMJ Qual Saf 2011;20:1043—51.

[17] Aranaz-Andres JM, Aibar-Remon C, Vitaller-Murillo J, Requena-Puche J, Terol-Garcia E, Kelley E, et al. Impact and preventability of adverse events in Spanish public hospitals: results of the Spanish National Study of Adverse Events (ENEAS). Int J Qual Health Care 2009;21(6):408—14.

[18] Sari AB-A, Sheldon TA, Cracknell A, Turnbull A, Dobson Y, Grant C, et al. Extent, nature and consequences of adverse events: results of a retrospective casenote review in a large NHS hospital. Qual Saf Health Care 2007;16:434—9.

[19] Sousa P, Uva AA, Serranheira F, Nunes C Leite ES. Estimating the incidence of adverse events in Portuguese hospitals: a contribution to improving quality and patient safety. BMC Health Serv Res 2014;14:311.

[20] Healthcare Pricing Office. Hospital in-patient enquiry scheme. 2009.

[21] Health Service Executive. National Service plan. 2009. Available from: http://www.hse.ie/eng/services/Publications/corporate/National_Service_Plan_2009.pdf [last accessed 15 January 2019].

[22] Burns K, Foley M, Donlon S. Point prevalence survey of hospital-acquired infections & antimicrobial use in European acute care hospitals: May 2012 — Republic of Ireland national report. Health Protection Surveillance Centre; 2012.

[23] Hoogervorst-Schilp J, Langelaan M, Spreeuwenberg P, de Bruijne MC, Wagner C. Excess length of stay and economic consequences of adverse events in Dutch hospital patients. BMC Health Serv Res 2015;15:531.

[24] National Clinical Effectiveness Committee. Prevention and control methicillin-resistant *Staphylococcus aureus* (MRSA) national clinical guideline No. 2. Dublin, Ireland: Department of Health; 2013.

[25] Department of Health. Ireland's national action plan on antimicrobial resistance 2017-2020. (iNAP). Dublin, Ireland: Department of Health; 2017.

[26] European Centre for Disease Prevention and Control. Annual epidemiological report on communicable diseases in Europe 2008. Stockholm: European Centre for Disease Prevention and Control; 2008.
[27] Plowman R, Graves N, Griffin M, Roberts J, Swan A, Cookson B, et al. The rate and cost of hospital-acquired infections occurring in patients admitted to selected specialties of a district general hospital in England and the national burden imposed. J Hosp Inf 2001;47:198—209.
[28] Ryan P, Skally M, Duffy F, Farrelly M, Gaughan L, Flood P, et al. Evaluation of fixed and variable hospital costs due to *Clostridium difficile* infection: institutional incentives and directions for future research. J Hosp Inf 2017;95:415—20.
[29] Thomas EJ, Studdert DM, Newhouse BI, Zbar K, Howard M, Williams EJ, et al. Costs of medical injuries in Utah and Coloradao. Inquiry 1999;36(3):255—64.