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Bed-days and costs associated with the inpatient burden of healthcare-associated infection in the UK

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S U M M A R Y

Background: Healthcare-associated infection (HAI) is associated with increased morbidity and mortality resulting in excess costs.
Aim: To investigate the impact of all types of HAI on the inpatient cost of HAI using different approaches.
Methods: The incidence, types of HAI, and excess length of stay were estimated using data collected as part of the Evaluation of Cost of Nosocomial Infection (ECONI) study. Scottish NHS reference costs were used to estimate unit costs for bed-days. Variable (cash) costs associated with infection prevention and control (IPC) measures and treatment were calculated for each HAI type and overall. The inpatient cost of HAI is presented in terms of bed-days lost, bed-day costs, and cash costs.
Findings: In Scotland 58,010 (95% confidence interval: 41,730–74,840) bed-days were estimated to be lost to HAI during 2018/19, costing £46.4 million (19m–129m). The total annual cost in the UK is estimated to be £774 million (328m–2,192m). Bloodstream infection and pneumonia were the most costly HAI types per case. Cash costs are a small proportion of the total cost of HAI, contributing 2.4% of total costs.
Conclusion: Reliable estimates of the cost burden of HAI management are important for assessing the cost-effectiveness of IPC programmes. This unique study presents robust economic data, demonstrating that HAI remains a burden to the UK NHS and bed-days capture the majority of inpatient costs. These findings can be used to

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inform the economic evaluation and decision analytic modelling of competing IPC programmes at local and national level.

Introduction

Healthcare-associated infection (HAI) represents a major issue for health services, patients, and public authorities [1]. These potentially avoidable events are associated with increased morbidity and mortality, resulting in excess management costs [1–3]. The Evaluation of Cost of Nosocomial Infection (ECONI) study estimated HAI incidence of 0.76% (95% confidence interval (CI): 0.72–0.81) with 7437 (7021–7849) HAI cases in teaching and large general hospitals in NHS Scotland in 2018/19 [4].

Many studies have examined the costs associated with HAIs but comparisons among estimates can be challenging due to the differences between settings, patient groups, and methods of attributing costs [5]. Few studies have examined the whole-hospital incidence and all HAI types. The last study to do this for the UK by Plowman *et al*. found HAI to be a considerable burden, equivalent of 9.1% of the total 1994/5 inpatient acute, obstetric, and geriatric programme budget in England [6]. These cost estimates arose from methods that did not account for the time-varying nature of HAI and are likely to have been overestimated [7]. In the intervening period the UK and other countries established national infection prevention and control (IPC) programmes focused on HAI prevention [8,9]. Since the 1990s there have been significant changes in the age and frailty of the hospital population, complexity of treatments, use of invasive devices, antimicrobial resistance (AMR) and targeted IPC measures, all of which have affected the incidence and impact of HAI. Accurate and current information is needed to optimize decision-making when selecting between competing IPC programmes to ensure the most efficient programmes are implemented [10,11].

The aim of this study was to estimate the costs of different types of HAI in acute hospitals in NHS Scotland using a variety of approaches, and to extrapolate to the whole of the UK. One of the major costs of HAI can be shown by the number of bed-days released by its prevention. Released hospital beds can be valued in monetary terms by examining how much they historically cost the hospital to supply, the accounting cost. Bed-days include a high proportion of fixed costs and some variable costs [11]. When HAI cases are prevented, releasing bed-days, resources represented by fixed costs can be redeployed for other uses but not recovered, whereas variable costs can be recovered as cash savings. The cost of HAI is presented as natural units of bed-days lost due to HAI and bed-days valued using accounting costs. The accounting costs represent valuations of resources for alternative uses. The cash or variable costs related to the treatment of HAI in NHS hospitals are also calculated separately. The cash costs of treating HAI represent potential savings if HAI cases were prevented [11].

This study presents new information for healthcare decision-makers which can inform economic decision-making for competing IPC programmes locally and nationally.

Methods

To estimate the inpatient cost of HAI on the health service, the incidence rates and estimates of excess length of stay (LOS) derived from the ECONI study were combined [4,12]. ECONI was a two-centre, prospective observational incidence study with a nested case–control study [13]. ECONI took place in one teaching hospital and one large general hospital in NHS Scotland in 2018/2019. The cost of HAI to the NHS acute care sector was estimated by taking the following steps. First, the expected number of annual HAI cases was estimated. Second, the extra resources used to treat the average case were identified. Third, those resources used for the treatment of HAI were valued in monetary terms. The costs from the ECONI study were extrapolated to produce an estimate for the UK.

Expected annual HAI cases

The expected number and types of annual HAIs were estimated using data collected as part of the ECONI study [4]. ECONI reported the incidence of HAI using standard case definitions of the European Centre for Disease Prevention and Control [13]. Incidence rates of HAI per 100,000 acute occupied bed-days (AOBD) in the study hospitals were used to estimate HAI incidence in NHS Scotland. National estimates of HAIs were derived by applying the incidence within each specialty group to the total annual overnight admissions within NHS Scotland [4]. The nested case–control sample included ∼5% of the HAI cases and was used to calculate the cash cost of antibiotic treatment only (see Appendix) [14].

Resources used to manage the average HAI case

HAI cost is mainly driven by excess LOS in the hospital [15]. During these extra days in hospital, HAI patients consume a mix of resources represented by fixed and variable costs. Fixed costs do not change with the number of patients treated and, in the NHS, represent buildings and staff; variable costs change with the number of patients treated and include consumables such as drugs and disposable equipment. Estimates of excess LOS due to HAI were produced for each HAI type and all HAI using a multi-state modelling approach that took account of time-varying exposures and the competing risks of death and discharge [16,17]. The multi-state model estimated excess LOS, for each HAI type, that could have been spent in any clinical area inclusive of intensive care unit (ICU), high-dependency unit (HDU) or other wards. The methods and results for the multi-state model are described in detail elsewhere [12]. Estimates of annual bed-days lost to HAI depend on both estimated incidence and excess LOS due to HAI [4,12].

Table I
Bed-day unit costs (£)[a]

Unit cost	Mean	SD	Distribution
Bed-day total cost	799.17	535.37	Log–normal
Bed-day direct cost	519.38	344.27	Log–normal

SD, standard deviation.
[a] Source: Information Services Division (ISD) Scotland [26].

Valuing resources used in the treatment of HAI in monetary terms

To value bed-days lost due to HAI, the 'total' and 'direct' accounting unit costs were calculated. These are mostly fixed costs and are based on a top-down valuation approach with gross-costing methodology [18]. Total costs include capital, overheads, staff, pharmacy, and laboratory costs. The total and direct costs were calculated using routinely reported historical data from NHS Scotland [19]. Direct costs include staff and consumable costs outlined above and exclude capital and overhead costs. Direct costs can be directly attributed to patient care and have been used previously to estimate the costs of treating HAI [20–25]. Unit cost estimates were weighted by the total number of discharges across all specialties from April 2017 to March 2018 in Scottish teaching hospitals and large general hospitals (see Appendix). Unit costs were aggregated across ICUs, HDUs, and other wards to match the estimates of the multi-state model [12]. Unit cost raw data were assumed to be log–normally distributed. In cost estimation CIs were calculated by taking 5000 Monte Carlo draws from log–normal distributions fitted to the unit cost data. Bed-day unit costs were based on Scottish reference costs and are presented in Table I [26]. Standard deviations in Table I reflect the substantial variability in bed-day costs across specialties and hospitals in Scotland.

The excess variable or cash cost incurred for each type of HAI was also calculated separately. These cash costs excluded fixed staff costs and were grouped into diagnostic tests and IPC consumables (including cleaning materials and antibiotic drugs). Diagnostic tests were defined according to HAI type and causative organisms reported in the ECONI study [4]. IPC and cleaning consumable costs were calculated for each level of transmission-based precautions (TBP) required for treatment. This included mapping the proportion of each HAI type which required use of TBP based on the Scottish National IPC manual and consultation with IPC experts [27]. The unit costs of IPC consumables were based on a mix of existing literature and expert opinion (see Appendix for full details).

Data on antibiotic prescribing in hospital was collected from the nested case–control sample of the ECONI study. The British National Formulary was used to cost antibiotics [28]. The costs were recorded in the week after data collection had been completed. Cash costs were multiplied by the estimated annual number of HAIs to calculate cash treatment by HAI type and a total. All cash costs were calculated in 2019 pound sterling (£); further detail is presented in the Appendix.

UK extrapolation of bed-day HAI costs

The ECONI study estimated incidence 0.76% (95% CI: 0.72–0.81) was applied to the UK total elective and emergency patient admissions in the financial year April 2017 to March 2018 to produce national estimates of costs [29–32]. This extrapolation assumes that the two hospitals of the study were representative of other acute hospitals in Scotland and the UK in terms of specialties, excess LOS, and bed-day unit costs [19].

Estimation of lost bed-days and costs due to HAI

Estimates of annual bed-days lost, for each HAI type and overall HAI, along with bias-corrected confidence intervals, using 5000 non-parametric bootstrap samples, were based on incidence and excess LOS estimated elsewhere [4,12]. In this study the annual and per-case cost of HAI is defined as the product of vectors of unit costs and excess resources consumed due to HAI. Point estimates of annual and per-case bed-day costs, for each HAI type and overall HAI, were calculated using annual and per-case bed-days lost multiplied by bed-day unit costs and excess LOS multiplied by bed-day unit costs, respectively. To estimate 95% CIs of annual and per-case costs, 5000 Monte Carlo simulations were drawn from log–normal distributions fitted to the data shown in Table I [17].

Cash costs were calculated separately using a different analytical process (see Appendix). Due to the way cash costs were calculated, point estimates of the unit costs were used in the calculation of cash costs. Therefore, no CIs are provided for cash costs related to IPC and treatment of HAI.

Table II
Incidence, average excess LOS and bed-days lost by HAI type in Scotland

HAI	Incidence rates per 100,000 AOBD (95% CI)	Estimated annual number of HAI cases (95% CI)	Average excess LOS[a] per HAI (95% CI)	Total annual bed-days lost to HAI[b] (95% CI)
BSI	35.0 (31.3–39.5)	1389 (1245–1570)	11.4 (5.8–17.0)	15,830 (7550–23,950)
GI	31.6 (28.2–36.3)	1256 (1122–1440)	6.0 (−0.7 to 12.7)	7540 (0–16,100)
LRI	26.2 (3.6–30.7)	1041 (937–1218)	7.3 (1.8–12.7)	7600 (1300–13,540)
PN	15.9 (13.7–19.2)	630 (544–764)	16.3 (7.5–25.5)	10,270 (4170–16,380)
SSI	25.8 (22.8–30.5)	1023 (904–1210)	9.8 (4.5–15.0)	10,030 (4190–15,900)
UTI	41.0 (36.6–46.2)	1628 (1454–1836)	−1.0 (−4.3 to 2.3)	0 (0–4,180)
Other	12.0 (9.5–15.8)	475 (378–628)	14.0 (−3.9 to 31.8)	6650 (0–16,360)
All HAI	187.2 (176.8–197.6)	7437 (7021–7849)	7.8 (5.7–9.9)	58,010 (41,730–74,840)

LOS, length of stay; HAI, healthcare-associated infection; AOBD, acute occupied bed-days; CI, confidence interval; BSI, bloodstream infection; GI, gastrointestinal infection; LRI, lower respiratory tract infection; PN, pneumonia; SSI, surgical site infection; UTI, urinary tract infection; 'Other' includes: SST, skin soft tissue; BJ, bone and joint; CV, cardiovascular; EENT, eye, ear, nose, and throat; and SI, systemic infection.
[a] Excess LOS is expressed in additional days per case.
[b] NHS Scotland acute hospitals.

Ethics

This study was surveillance and therefore was confirmed as ineligible for ethical review (A. Bailey. Personal communication to S. Stewart, 2016, South East Scotland Research Ethics Service). The case–control study component of the study received a favourable ethical opinion from the Scotland A Research Ethics Committee on March 3rd, 2017 (Reference 16/SS/0199). It was approved by national information governance approvals: Public Benefit of Health and Social Care: Incidence study: 1617-0037.

Results

The incidence rate and average excess LOS from the ECONI study and total bed-days lost by HAI type for teaching and general hospitals in Scotland are shown in Table II. These are based on the total annual admissions to teaching and general hospitals in NHS Scotland in 2018/19.

Bloodstream infection (BSI) was the HAI type with the greatest total annual impact in terms of bed-days lost, followed by pneumonia and surgical site infection (SSI). Urinary tract infection (UTI) was shown to have a negative impact on LOS in the multi-state model. In practice this means that on average UTI did not increase LOS, and it was assumed that there were zero additional days for these patients. In total there were 58,010 bed-days (95% CI: 41,730–74,840) lost in a year due to all HAI types.

Cost per case and annual inpatient costs in Scotland are shown in Table III. The total cost attributable to HAI treatment annually in NHS Scotland is estimated to be £46.35 million (19.4m–128.8m). The direct cost due to HAI is estimated to be £30.11 million (14.1m–74.4m) per year.

The extrapolation of the costs for the whole of the UK is shown in Table IV. Total costs in the UK based on total admissions are estimated to be £774 million (328 million to 2.2 billion) annually. Direct costs are estimated to be £503 million (236 million to 1.2 billion) per year.

The costs of consumable items that could be saved in the short term are shown in Table V. The total cost of these items varies by HAI type. These costs are small in comparison to staff time and other fixed resources. The total annual estimate is approximately £1.1 million across acute hospitals in the Scottish NHS. Cash costs are ~2.4% of the estimated total cost of HAI and 3.7% of the direct cost of HAI in Scotland.

Table IV

Annual total inpatient cost of HAI in the UK[a]

Annual total cost in the UK (£ million per year)	Annual direct cost in the UK (£ million per year)
774 (328–2,192)	503 (236–1,217)

Annual UK total and direct costs are based on ECONI HAI incidence: 0.76% (0.72–0.81).

[a] Values are mean (95% confidence interval).

Discussion

The ECONI study is the first in the UK to report whole-hospital incidence of HAI since the study by Plowman *et al.*, which was based on data from more than 20 years ago [6]. It was estimated that in Scotland 58,010 (95% CI: 41,730–74,840) bed-days were lost due to HAI each year. These occupied beds are the main economic cost arising from HAI. The impact of lost bed-days in a system like the NHS results in an increase in waiting lists, which means that potential patients are delayed in accessing services. This size of the loss equates to 159 beds or a small general hospital of 180 beds (assuming average bed occupancy of 88%) being occupied for a whole year with HAI cases. Alternatively, the impact of HAI can be shown by the number of elective patients who could have been treated after a 10% reduction in HAI rates. Given that LOS for elective patients in NHS Scotland is on average 3.4 days, then 1700 additional elective patients could be treated annually if 10% of HAI is prevented [33]. Estimated lost bed-days represent the opportunity cost of HAI expressed in natural units. The opportunity cost of a bed-day can be defined as the forgone benefit of the best alternative use of the resource such as treating another patient. In the NHS high demand means that a released bed is very valuable since a new patient will always occupy it, but in situations of spare capacity the value would be lower if a bed remains empty. Bed-days are a unit of currency familiar to healthcare decision-makers who manage resources with a high proportion of fixed costs.

The total cost valuation of the lost bed-days due to HAI was £46.35 million (95% CI: 19m–129m) and the direct cost was £30.11 million (14m–75m). In 2018/19 the total acute inpatient expenditure in Scotland was about £4 billion [34]; this sets the total cost of HAI at ~1.1% of the total acute inpatient expenditure in NHS Scotland. These are mostly fixed costs that cannot be recovered as savings if HAI is prevented, since they are based

Table III

Cost per case for each HAI type and annual cost of HAI in NHS Scotland[a]

HAI	Cost per case for each HAI type and overall (£)		Annual cost in NHS Scotland (£ million)	
	Total cost per case	Direct cost per case	Total cost	Direct cost
BSI	9,109 (3,511–28,210)	5,917 (2,552–15,438)	12.65 (4.82–38.96)	8.22 (3.45–21.94)
GI	4,794 (445–19,835)	3,114 (192–10,401)	6.02 (0.52–24.83)	3.91 (0.24–14.11)
LRI	5,833 (1,729–20,019)	3,789 (1,234–11,684)	6.07 (1.66–21.25)	3.94 (1.17–11.84)
PN	13,024 (4,808–45,061)	8,460 (3,432–23,548)	8.20 (2.99–25.88)	5.33 (2.01–14.44)
SSI	7,830 (2,987–24,993)	5,086 (2,095–14,433)	8.01 (2.95–27.02)	5.20 (1.96–13.45)
UTI	0 (0–2,109)	0 (0–1,304)	0 (0–3.63)	0 (0–2.21)
Other	11,186 (0–45,319)	7,266 (0–26,523)	5.31 (0.05–24.45)	3.45 (0–12.77)
All HAI	6,232 (2,733–18,181)	4,048 (1,927–9,591)	46.35 (19.43–128.81)	30.11 (14.12–74.46)

HAI, healthcare-associated infection; CI, confidence interval; BSI, bloodstream infection; GI, gastrointestinal infection; LRI, lower respiratory tract infection; PN, pneumonia; SSI, surgical site infection; UTI, urinary tract infection; 'Other' includes: skin/soft tissue; bone and joint; cardiovascular; eye, ear, nose, and throat; and systemic infection.

[a] All values are mean (95% confidence interval).

Table V
Costs of annual IPC, laboratory materials, and antibiotics used in the treatment of HAI in Scotland

HAI	IPC and laboratory costs (£)				Antibiotic costs (£)[a]	
	Mean IPC cost per HAI case	Mean laboratory test cost per HAI case	Total IPC and laboratory cost per HAI case	Annual cost in Scotland	Cost of antibiotics per HAI case	Annual cost in Scotland
BSI	15.76	23.13	38.89	54,018	91	126,399
GI	67.10	65.52	132.62	166,571	43	54,008
LRI	22.53	39.10	61.63	64,157	125	130,125
PN	24.01	36.41	60.42	38,065	280	176,400
SSI	12.62	27.10	39.72	40,634	454	464,442
UTI	14.96	19.03	33.99	55,336	7	11,396
Other	8.44		8.44	4,009	4	1,900
All HAI				422,790	91	676,767

IPC, infection prevention and control; HAI, healthcare-associated infection; BSI, bloodstream infection; GI, gastrointestinal infection; LRI, lower respiratory tract infection; PN, pneumonia; SSI, surgical site infection; UTI, urinary tract infection; 'Other' includes: skin/soft tissue; bone and joint; cardiovascular; eye, ear, nose, and throat; and systemic infection.
[a] Antibiotic costs were calculated from the case–control sample and not directly comparable with other results presented in this study.

on historical accounting unit costs. However, it is still important to consider costs in this way so that comparisons can be made with other NHS spending that is reported in similar terms. These costs also represent a monetary valuation of benefits from alternative uses of these resources when HAI is prevented. Direct costs are a representation of staff and consumable resources that could have been used to treat other patients if HAI rates were reduced.

The top three HAI types which had the greatest cost impact were BSI, pneumonia, and SSI (Table III). HAI cost is estimated as a combination of incidence and excess LOS, and the rank order of HAI type changes according to the impact on either incidence or LOS. For example, according to ECONI incidence, UTIs are the most common infections in Scotland but these are usually easily treated and thus have minimal impact on inpatient resources. This does not mean that IPC teams should disinvest in UTI prevention since these high-incidence infections frequently require antibiotic treatment, thus contributing to AMR. UTIs were also found to be one of the most common primary infection types leading to secondary BSI [4]. BSI is the second most common HAI type and has a relatively large impact on LOS (11.4 additional days on average). BSI is very costly, and targeting investment in IPC measures to reduce this type of HAI is likely to be cost-effective. Pneumonias also have serious consequences for the patients and can be difficult to treat, increasing LOS by more than 16 days on average, but they were less frequent than other HAIs. Nevertheless, IPC measures to prevent pneumonias could represent a good use of resources given the high cost per case of these infections. Outbreaks that would cause an increase in viral respiratory tract infection can be very costly for the health service and vigilance against these is required. SSIs have a lower cost per case than pneumonias but are more frequent, making these the second most costly HAI type annually in Scotland.

The cost of HAI was extrapolated to the whole of the UK and is estimated to be at £774 million (95% CI: 328m to 2,192m) and direct costs at £503 million (236m–1,217m) annually. The total cost of HAI is estimated to be at 0.62% of the NHS total spending in the four UK nations in 2018 and is associated with ∼968,000 lost bed-days annually. This is much lower than the 9.1% and 3.64 million lost bed-days estimated by Plowman *et al.* more than 20 years ago [6]. Since the 1990s, changes in the hospital population, treatments, use of devices, antimicrobial resistance and IPC measures have affected the incidence and impact of HAI on the health service. The extrapolation results in this study should be interpreted with caution since they assume a similar mix of hospitals, specialties, and severity of illness across the UK.

Whereas total costs may represent historical spending to supply these beds, they do not necessarily represent their value in terms of opportunity costs, especially in situations of spare capacity. Opportunity costs are a more useful measure for decision-making under conditions of scarce resources but estimating these accurately may be difficult [35]. There have been attempts to estimate the opportunity cost of a bed-day using willingness-to-pay (WTP) surveys in other countries [36,37]. For example, Page *et al.* estimated opportunity costs using a WTP survey, for bed-days released by IPC programmes, elicited from CEOs of acute hospitals in Australia [37]. These estimates suggest that the total accounting cost to opportunity cost ratio is approximately equal to 3.7, which would imply an economic value of £216 for each bed-day in this study. A bed-day cost at this level would result in yearly opportunity costs in Scotland of up to £16 million, falling at the lower end of the estimated direct cost confidence interval (95% CI: 14m–75m). The true economic value or opportunity cost of the occupied bed-day in teaching and general hospitals in the UK is unknown, and using WTP estimates from another country or other types of hospitals would introduce sources of uncertainty. WTP can over- or underestimate the cost depending on demand for hospital beds, and estimates would be much higher in an infection outbreak or pandemic. In a WTP study in European tertiary hospitals Stewardson *et al.* recognized that a limitation of this approach is that WTP measures purchase intention, not actual cost [36]. Additionally, they found that WTP values depended on the type of hospital reimbursement [36]. Other studies also found that the hospital remuneration pro-cess had implications in how hospital executives view infection prevention [38,39].

This study values resource lost to HAI in total costs and direct costs using estimates of HAI incidence and excess LOS that are based on methodologies that minimize bias [4,12]. Most UK hospitals are operating close to full capacity with long waiting lists, which suggests that, when HAI is prevented, resources could be readily redeployed to treat other patients [40,41]. This means that the valuation of HAI cost in this study represents resources with alternative uses. In addition, this study allows a comparison of the cost of different HAI types, and at the same time contrasts incidence with resource use, which is relevant to IPC planning. Another strength of this study is the probabilistic methodology that combined estimates of HAI incidence, excess LOS, and bed-day unit costs, and accounted for all types of uncertainty in the parameters. Previously in this literature studies have reported costs without fully accounting for all sources of uncertainty [38,42—45].

This study has several limitations. It was not conducted using a bottom-up micro-costing approach [18]. An example of this method is the patient-level information costing system (PLICS) but this was not routinely available during the study period. PLICS is a patient-level approach that can be used to standardize the method of reporting cost information across the health service. PLICS has the potential to be more accurate than gross-costing methods but is still limited by unit costs that do not reflect opportunity costs, and staff costing may occasionally be based on averages resembling a gross-costing methodology. A study in an English NHS hospital using PLICS to report the economic burden of SSI reported an attributable cost of SSI of £5,239 (95% CI: 4,622—6,719) [38]. This study estimates that the attributable direct hospital cost of SSI was £5,086 (2,095—14,433). Another limitation of this study is that the multi-state model estimates of excess LOS do not distinguish between facilities that have completely different cost profiles. For example, if 10% of the excess LOS took place in an ICU bed, this would increase estimated costs by ~14%. Heister *et al.* in a study of *C. difficile* show that multi-state models may also underestimate excess LOS, which means that the results of this study could be a conservative estimate of the true cost of HAI [46]. Furthermore, since antibiotic costs are based on a smaller sample, these costs may not be directly comparable with the rest of the results.

Bed-day costs reported previously in the literature mostly relate to capital costs, overheads, and fixed contracts that do not change in the short term [11]. Since the cost of facilities and staff are fixed under normal circumstances there is small potential for any annual saving that could be achieved by preventing HAI. Any savings would relate to the consumable items that are purchased as they are consumed. Gastrointestinal infections (GIs) and pneumonias had the highest IPC and laboratory cash costs per case, with GIs having the greatest annual impact. This study shows that pneumonias are highly resource intensive, both in terms of fixed costs and variable costs. While the results of this study have shown that Scottish annual cash costs for all HAI types are relatively small at approximately £1.1 million per year, this money could eventually be reinvested if HAI cases were prevented. Plowman *et al.* suggested that cash costs are 11% of the total costs [6]. The results of this study suggested that cash costs are a much smaller proportion of costs at 2.4% of the total and 3.8% of direct costs. This means that any expected cash savings from HAI prevention would be very small. Preventing HAI may only release relatively small funds as cash savings, but there is an additional benefit — that is not included in these monetary valuations — of reducing antibiotic consumption [47]. The human cost of HAI should also be taken into account when evaluating HAI prevention since it is also not included in these monetary costs.

A recent meta-analysis concluded that HAI reduction of between 35% and 55% may be possible with the implementation of multi-faceted interventions [48]. However, preventable proportions of HAI may decrease over time as IPC initiatives are successfully implemented. Reductions shown in some of the earlier studies within this meta-analysis would not be achievable today, as many of the proposed interventions have been implemented in some way. It is likely that realistic reductions in overall HAI numbers in Scotland would be lower than Schreiber *et al.* reported, especially given the low proportion of surgical and device-related HAIs identified in the ECONI study [4,48]. Exaggerated estimates of the cost of HAI and the potential benefits from prevention of HAI may lead policy-makers to be disappointed when IPC programmes turn out to be less efficient than expected.

Although considerable progress has been made in evaluating IPC measures with cost-effectiveness modelling approaches, these analyses rely heavily on unbiased information [49]. When seeking funding, 'attention grabbing' costs are frequently quoted in order to convince policy-makers to invest in IPC measures among other interventions. Within the literature there are also attempts to compare the cost of HAI with other conditions, e.g. cancers, with the intention to focus policy-makers' attention on IPC and HAI prevention. However, as discussed elsewhere, it is patients with these conditions who are most at risk of developing HAI [50]. Rather than promoting such competition for resources among patient groups, studies should include integration of IPC measures in order to maximize the efficacy of existing treatments for those most at risk of developing HAI. This study reports the cost of HAI using a variety of measures that can reliably inform future economic evaluations of IPC programmes.

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Author contributions

S.M. contributed to aspects of the study design and led data collection for economic analysis, calculated the total and direct costs and prepared the manuscript. S.S. led the study design, wrote study protocols and ethics and Public Benefit and Privacy Panel approvals, patient-facing materials, contributed to the design of the collection tools, contributed to the statistical analysis, developed the manuscript and the cash treatment costs. N.G. prepared the manuscript and contributed to the study design. H.M. contributed to the study design, led on health economic aspects of the study design and contributed to the manuscript. C.R. contributed to the concept of the study, study design, statistical analysis plan and the manuscript. S.K., J.P. and K.K., undertook the statistical analysis and prepared results. L.H. contributed to the development of study design, protocol and data management and contributed to the final manuscript. M.A. contributed to the final manuscript. S.D. and B.C. are the Principal Investigators at the recruiting sites and contributed to the final manuscript. J.R. conceived the study, is Chief Investigator for the study and contributed to the manuscript.

Non-author collaborators

The ECONI Steering Committee. M.A. represented the funder, A.L., R.D., A.M., M.S. and J.I. represented the Scottish Government HAI policy unit on the Steering Committee. E.R. and L.R. represented Infection Prevention Society (IPS). M.W., L.B., and M.R. were lay representatives on the Steering Committee and M.W. and L.B. contributed to the development of the patient-facing materials for the study. Committee: Professor J. Reilly (J.R.), Professor M. Adil (M.A.), Dr H. Mason (H.M.), Professor C. Robertson (C.R.), Professor N. Graves (N.G.), J. Ives (J.I.), M. Syme (M.S.), R. Dunk (R.D.), A. Mullings (A.M.), E. Ross (E.R.), L. Ritchie (L.R.), Professor S. Dancer (S.D.), Dr B. Cook (B.C.), Professor A. Leonard (A.L.), M. Whyte (M.W.), M. Rodgers (M.R.), L. Brown (L.B.), S. Stewart (S.S.).

Conflict of interest statement

None declared.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jhin.2020.12.027.

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