Reducing the number and impact of outbreaks of nosocomial viral gastroenteritis: time series analysis of a multidimensional quality improvement initiative

Caroline Mitchell, PhD, Head of Infection and Clinical Safety, Department of Infection Prevention, Portsmouth Hospitals NHS Trust, Portsmouth PO6 3LY, UK & Honorary Senior Lecturer, Department of Infection & Immunity, University College, London WC1E 6BT, UK

Paul Meredith, PhD, Information Analyst, Research & Development Department, Portsmouth Hospitals NHS Trust, Portsmouth PO6 3LY, UK

Matthew Richardson, MPH, Infection Prevention Specialist, West Hampshire Clinical Commissioning Group, Eastleigh SO50 5PB, UK

Peter Greengross, FRCS, FFPH, Honorary Senior Clinical Research Fellow, Department of Primary Care and Public Health, Imperial College Healthcare NHS Trust, London W6 8R, UK & Medical Director, The Learning Clinic, 7 Lyric Square, London W6 0ED, UK

Gary B Smith, FRCA, FRCP, Visiting Professor, School of Health & Social Care, University of Bournemouth, Bournemouth BH1 3LT, UK

Corresponding author:
Professor G B Smith, FRCA, FRCP,
Centre of Postgraduate Medical Research & Education (CoPMRE),
The School of Health & Social Care,
Bournemouth University, Royal London House,
Christchurch Road, Bournemouth,
Dorset BH1 3LT, United Kingdom

Tel: +44 (0) 1202 962782
Fax: +44 (0) 1202 962218
Email: gbsresearch@virginmedia.com

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ABSTRACT

Background: Nosocomial norovirus infections and their control measures disrupt patient care, increase staff workload and raise healthcare costs.

Objective: To determine the impact on outbreaks of nosocomial viral gastroenteritis, staff and patients affected, and bed closures of a multidimensional quality improvement (QI) initiative focused on education; improved patient surveillance; early automated recognition and notification of infection of index patients; and proactive care and control measures.

Methods: In a pragmatic, retrospective, observational study, we compared numbers of suspected/confirmed norovirus outbreaks at Portsmouth Hospitals NHS Trust (PHT) with regional and national data, before and after a multidimensional QI initiative. We also compared mean daily bed closures due to norovirus-like symptoms. At PHT only we recorded patient and staff numbers with norovirus-like symptoms, and days of disruption due to outbreaks.

Results: Annual outbreak numbers fell between 2009-2010 and 2010-2014 by 91% at PHT, compared to 15% and 28% for Wessex and England, respectively. After April 2010, recorded outbreaks were 8 (PHT), 383 (Wessex) and 5063 (England). For the winter periods from 2010/2011 to 2013/2014, total bed closures due to norovirus were 38 (PHT; mean 0.5 per week), 3565 (Wessex hospitals; mean 48.8 per hospital per week) and 2730 (England; mean 37.4 per hospital per week). At PHT, patients affected by norovirus-like symptoms fell by 92%, affected staff by 81% and days of disruption by 88%.

Conclusions: A multi-year QI programme, including use of real-time electronic identification of patients with norovirus-like symptoms, and an early robust response to suspected infection, resulted in virtual elimination of outbreaks. The ability to identify index cases of infection early facilitates prompt action to prevent ongoing transmission and appears to be a crucial intervention.

BACKGROUND

Norovirus is the most common cause of epidemic gastroenteritis.[1-4] Outbreaks of hospital-acquired norovirus infection occur frequently, especially in winter.[4-6] Predisposing factors include: patient-staff and patient-patient contact; frequent inter-ward transfers; poor environmental and staff hygiene; high bed occupancy rates; and staff movement within the hospital.[7-9] As different staff look after different

patients, even within the same ward, outbreak recognition is often delayed.

In hospital, norovirus control measures focus on breaking the chain of transmission through: rigorous hand hygiene; environmental cleaning and disinfection of contaminated surfaces; isolating suspected and confirmed cases, and their contacts; limiting staff movement between infected and non-infected areas; and restriction of visitors.[6-8] Norovirus infections and their control measures disrupt patient care, increase staff workload and raise healthcare costs.[4,10-12] Public Health England (PHE) has reported that, on average, outbreaks are associated with 13,000 patients and 3,400 staff becoming ill, 8,900 days of ward closure and the loss of over 15,500 bed-days, annually.[4] In one recent UK publication, 192 outbreaks cost an estimated £1.2 million.[11]

Since 2008, Portsmouth Hospitals NHS Trust (PHT) has introduced interventions to improve patient surveillance, accelerate identification of patients with norovirus-like symptoms, and ensure appropriate proactive management (Table 1). To measure their impact on outbreaks, we undertook a retrospective analysis and compared the results with contemporaneous national and regional data.

Table 1: The multidimensional quality improvement initiative

Intervention (Implementation date)	**Description of Intervention**	**Intervention type**	**Rationale**
A (May 2008)	'Stop the bugs' campaign.	Education	Local infection prevention initiative to increase hand hygiene and reduce transmission by faecal-oral route.
B (From late 2008)	Extended IPCT working hours.	Staffing	Provide a comprehensive reactive service modelled on patient need.
	IPCT staff trained to assess risk; obtain a clinical history; perform a physical examination; and provide proactive clinical management to stabilize vulnerable patients and minimize symptoms.	Education	Differentiation of infectious / non-infectious symptomatic patients. Reduction in patient morbidity. Reduction and source control to reduce environmental contamination and patient-to-patient transmission.
	Emphasis on single-room isolation; and identification and removal of the index case	Space	Removal of index source and reservoir.
	Ward hand hygiene audits and peer review of hand hygiene compliance	Audit	Reduce direct and indirect transmission through faeco-oral route
	Out-of-hours outbreak management transferred to IPCT	Staffing	Proactive (often onsite) cover out-of-hours by infection prevention specialist to manage 'suspected' outbreaks.
	Whole ward measures for enhanced cleaning, with special emphasis on touch point cleaning. Detergent & hypochlorite preparation used for cleaning all suitable surfaces.	Environmental	Reduce bio burden in ward environment and reduce direct and indirect transmission.
	Drinking water jugs emptied and washed in a dishwasher; Replenish regularly with fresh water; clean drinking fountains.	Environmental	Source control of water as a possible vector for Norovirus.
	Opened patient and staff food discarded. Beverage bays cleaned. Microwaves and fridges cleaned.	Environmental	Reduce transmission via contaminated food.
	IPCT visits at least twice daily. Ward 'attack' rate monitored.	Staffing	Monitor success of interventions, up scale or downgrade as required
	Staff and patients information leaflets distributed.	Education	Inform on control measures to enlist greater compliance with outbreak measures.
	Additional healthcare support worker employed.	Staffing	Provide ward staff and patients with IPCT support
C (June 2009)	New hospital block opens	Space	Increase in the number of single use occupancy, newer environment easier to clean.
D (April 2010)	IPC-Manager Software	Information system	Timely electronic surveillance of suspected cases of viral gastroenteritis.

IPCT = Infection and Prevention Control Team; IPC Manager = Infection Prevention & Control Manager

METHODS

Ethical Committee Approval

Ethical Committee Approval for this study is covered by Isle of Wight, Portsmouth and South East Hampshire Research Ethics Committee study ref. 08/02/1394.

Setting

The pragmatic, retrospective, observational study took place at PHT, an NHS Trust providing clinical services during the study period at five hospitals (Queen Alexandra Hospital (QAH), St. Mary's Hospital, Royal Hospital Haslar, Gosport War Memorial Hospital and Petersfield Community Hospital). PHT has ~7,000 staff, and admits ~140,000 patients annually to ~1000 inpatient beds. It provides all acute services except burns, spinal injury, neurosurgical and cardiothoracic surgery to a population of ~540,000. The study covers the period 1st September 2006-31st March 2014.

Pre-intervention practice regarding norovirus infection

Prior to winter 2008, PHT had no proactive, systematic norovirus infection surveillance. Ward staff reported clusters of symptomatic patients to the hospital's Infection and Prevention Control Team (IPCT) via telephone, often resulting in inaccuracies and delay. The IPCT investigated and managed outbreaks Monday-Friday 09:00-17:00; on-call microbiologists provided cover at other times. Outbreak confirmation was often made only by telephone. If necessary, infected wards were closed to admissions, transfers and discharges, thereby restricting staff, patient and visitor movement. Environmental cleaning was undertaken with hypochlorite. Symptomatic patients were frequently distributed across an affected clinical area; little effort was made to cohort or contain them. A philosophy of allowing episodes to 'burn out' existed. Wards were monitored once daily and re-opened 72h after the last symptomatic patient. A 'bare below the elbows' policy and emphasis on hand washing were already in place. [13,14]

Intervention: multidimensional quality improvement (QI) initiative

Introduction of a public health education campaign (Table 1, intervention A)

In May 2008, PHT introduced 'Stop the Bugs', a public health education campaign to prevent hospital infections through hand hygiene awareness,[15] employing: adverts on bus shelters, buses and billboards; a dedicated website; and media publicity. Posters, leaflets and alcohol gel dispensers were placed

throughout PHT.

Targeted norovirus care and control bundle (Table 1, intervention B)

Prior to winter 2008, core IPCT working hours were extended to 07:00-18:00 Monday-Friday, and out-of-hours outbreak management was transferred to on-call IPCT staff. Processes for reporting symptomatic patients remained unchanged, but telephone management alone was replaced by IPCT visits to every affected clinical area on day one of an outbreak. IPCT staff focused on two aspects; identification of infectious symptomatic patients, and measures to break the chain of transmission. Clinical assessment training was introduced for all IPCT nurses, enabling them to identify/exclude infections and manage them confidently. Ward hand hygiene audits were introduced and staff behavior regarding infection control, e.g. personal protective equipment usage, was monitored.

More assertive enhanced cleaning of outbreak areas was introduced, focusing on the whole ward. Domestic and clinical staff were trained to focus on cleaning key 'touch point' areas, as well as the general ward environment. All opened patient or staff food and drinks in affected areas were discarded; water jugs and cups were emptied, washed in a dishwasher and replenished with fresh supplies. An IPCT nurse specialist reviewed symptomatic patients, focusing on fluid and electrolyte balance, hypotension, and diarrhoea management. There was now an emphasis on removing symptomatic patients and protecting surrounding ones within six hours of a case being reported. Grouping of symptomatic patients was avoided, unless viral gastroenteritis was confirmed microbiologically. Ward closure was only contemplated if the ward 'attack rate' indicated uncontrolled norovirus transmission. Patient discharge home or to institutions capable of continuing effective isolation was permitted. A healthcare support worker was employed to aid rapid implementation of control measures (e.g., removing excess clinical equipment and patients' belongings; ensuring adequate supplies of disposable items), deliver patient and family education, and provide an early semi-permanent IPCT presence in outbreak areas. Information leaflets were disseminated to patients, visitors and staff.

Opening of a new hospital block (Table 1, intervention C).

In June 2009, a new 79,000m^2 hospital block opened at QAH, providing additional single-occupancy side rooms and greater space between beds.

Introduction of software designed to identify patients with norovirus-like symptoms in real-time (Table 1, intervention D).

In April 2010, the IPCT and The Learning Clinic (TLC) Ltd., London developed and introduced a computer application - VitalPAC Infection Prevention & Control Manager (IPC Manager) – to enable early identification of patients with norovirus-like symptoms. IPC Manager extends an existing hospital-wide electronic vital signs system (VitalPAC),[16,17] that enables nurses to record routine patient observations at the bedside on handheld devices. The handheld devices connect wirelessly to a hospital database server, where patient administration system and laboratory data are automatically integrated to create safety alerts. All vital signs, laboratory results and derived data are viewable throughout the hospital using mobile devices or desktop computers linked to the hospital intranet.[16] Of significance to the early identification of possible norovirus infection, each time vital signs are recorded VitalPAC directs staff to enter whether patients have nausea, vomiting or diarrhoea. VitalPAC uses an electronic version of the Bristol Stool Chart to facilitate easy entry of data regarding stool consistency.

IPC Manager integrates with VitalPAC, using automatically generated real-time feeds from microbiology reporting systems and submitted routine nursing observations to enable IPCT members to view the location, and clinical and infection status, of all patients instantaneously using handheld devices. IPC Manager also creates real-time alerts to the IPCT if observations suggest an index case or emerging outbreak, thereby enabling rapid intervention to prevent infection spread. IPCT staff can also record details of the infection control management of individual patients (e.g., isolation, suppression) or wards (i.e. closed/open) using IPC Manager.

Evaluation

Definitions

Norovirus infection was suspected if any of the following occurred within a 24h period in a single patient: ≥2 episodes of vomiting of suspected infectious cause; ≥2 loose stools; or ≥1 episodes of both symptoms.[18] Confirmed norovirus infection required laboratory confirmation of infection.[18]

A suspected norovirus outbreak was defined as ≥2 patients with suspected norovirus infection occurring on a ward.[18] A confirmed norovirus outbreak required microbiological confirmation.[18]

Outbreaks in different clinical areas were treated as separate events.

The outbreak duration was defined as the period (days) from onset to completion. Outbreaks were considered over when there had been no new cases for seven days in the clinical area.[18,19] The duration of disruption was defined as the number of days during which a clinical area was 'closed' or under 'special' infection control measures.

Data collection and analysis

For the period 1st September 2006-31st May 2014, we obtained the following data from PHT's IPCT records: (1) number and duration of suspected/confirmed norovirus outbreaks; (2) number of individual patients and staff with norovirus-like symptoms; and (3) number of days of disruption due to outbreaks. All of these are measures of the impact of the intervention, mediated via the impact of norovirus. Additionally, to reflect norovirus activity in the local community, we obtained the number of positive laboratory reports (from hospital and community requests) from the PHT microbiology laboratory records.

For comparison with PHT, we obtained data from PHE's hospital norovirus outbreak reporting system (HNORS)[20] for the number of (I) laboratory reports of norovirus and (II) suspected/confirmed norovirus outbreaks for (i) all English NHS hospitals and community settings, and (ii) 11 health providers in the Wessex Region - seven acute NHS Trusts (NHST) and NHS Foundation Trusts (NHSFT) (Appendix 1). Data were available for laboratory reports from 1st September 2006-31st May 2014, but for outbreaks from only 1st January 2009-31st May 2014 (HNORS was not launched until January 2009).

We calculated the percentage change between 2009/10 and the mean for 2010-2014, in numbers of positive laboratory reports and outbreaks for PHT, Wessex and England, and for affected patients, affected staff and days of disruption at PHT. We used a negative binomial regression model to calculate the incident rate ratio (IRR), in order to quantify the combined impact of: the 'Stop the Bugs' campaign and the targeted norovirus care and control bundle (comparing event rates in 2008/09 and 2007/08); the additional side rooms (comparing rates in 2009/10 and 2008/09); and IPC Manager (comparing the mean rate between 2010/11 and 2013/14 with that in 2009/10). We did not calculate

IRRs for laboratory reports, as these reflect a combination of community and hospital samples and are, of limited value in determining changes in hospital.

To identify the number of unavailable hospital beds due to norovirus-like symptoms, we compared the mandatory daily Winter Pressures Situation Report (SITREP) data[21] for the winter periods 2010/2011-2013/2014 for three groups: (1) 158 acute NHS Trusts in England; (2) the eight acute NHSTs/NHSFTs in the former NHS South Central Strategic Health Authority (SCSHA), other than PHT (Appendix 2); and (3) PHT alone. SITREPs have been used annually between early November and February/March since 2010/2011.[21] To address mergers of Wessex and English hospitals during the study, we used the number of Trusts in 2013-2014 when considering 'per hospital' data.

Total annual overnight hospital bed occupancy (%) figures for PHT for the study period were obtained from the NHS England website.[22]

RESULTS

(A) Comparison of PHT with other centres

The number of suspected/confirmed norovirus outbreaks at PHT, Wessex and England peaked in the winter annually (supplementary files 1-3). There was a sudden, sustained fall in outbreaks following winter 2009/10 at PHT, but this was not seen in Wessex or England (supplementary files 1-3). Comparing the mean annual outbreak numbers from April 2010-March 2014 with those for April-March 2009/10 demonstrates a 62% decrease in positive laboratory reports and a 91% reduction in outbreaks at PHT (Table 2). For the same comparison, positive laboratory reports and outbreaks fell by only 26% and 15%, respectively, in Wessex and 30% and 28%, respectively, in England (Table 2).

The fall in the outbreak incident rate between April-March 2009/10 and the period April 2010-March 2014 was significant at PHT (IRR, 0.095 [0.042-0.215]), but not in the hospitals in the Wessex (IRR, 0.854 [0.435-1.676]) or England (IRR, 0.724 [0.412-1.272]) groups.

After April 2010, there were only eight outbreaks (mean two per year) at PHT, compared with 383 in Wessex (mean 95.8 per year) and 5063 for England (mean 1265.8 per year) (Table 2).

Table 2: Annual numbers of positive laboratory reports and outbreaks for PHT, Wessex and England. Annual numbers of affected staff, affected patients, days of disruption and percentage overnight bed occupancy for PHT.

	2007/08	2008/09	2009/10	2010/11	2011/12	2012/13	2013/14		Mean for 2010/11 – 2013/14	% change comparing mean from April 2010-March 2014 with April–March 2009/10
PHT										
positive laboratory reports	56	81	78	23	28	55	13		29.75	-61.9%
outbreaks	59	31	21	3	2	2	1		2	-90.5%
affected patients	607	282	218	23	21	17	9		17.5	-92.0%
affected staff	87	40	54	20	11	8	1		10	-81.4%
days of disruption	458	177	112	21	19	9	3		13	-88.4%
bed occupancy (%)	81.1	78.5	83.1	81.0	86.9	88.5	91.2		-	-
Wessex										
positive laboratory reports	309	344	283	183	291	201	160		208.75	-26.2%
outbreaks	-	-	112	106	147	66	64		95.75	- 14.5%
England										
positive laboratory reports	6192	8148	11588	7998	9023	9552	5948		8130.25	- 29.8%
outbreaks	-	-	1746	1182	1605	1528	748		1265.75	- 27.5%

Percentage overnight hospital bed occupancy figures for PHT were obtained from KH03 data available on the NHS England website.[22]

For the combined winter periods from 2010/2011 to 2013/2014, the total number of beds closed due to norovirus-like symptoms at PHT was 38 (mean 0.5 per reporting week), compared with 3565 per Wessex hospital (mean 48.8 per hospital per reporting week) and 2730 per hospital in England (mean 37.4 per hospital per reporting week) (Figure 1). For PHT, there were only 3/73 weeks (4%) for which there were beds closed due to norovirus-like symptoms.

(B) Impact of interventions at PHT

Between February 2007 and January 2010, the peak monthly frequency of outbreaks varied between eight and 19, but the outbreak pattern was essentially unchanged by the introduction of interventions A-C. Figure 2 shows that, during the period when interventions A-C were introduced, annual outbreaks fell from 59 to 31 and 21 (April-March 2007/2008, 2008/2009 and 2009/2010). However, intervention D (April 2010 onwards) was associated with a greater fall to three, two, two and one in April-March 2010/2011, 2011/2012, 2012/2013 and 2013/2014, respectively (Table 2).

Similar patterns were seen following the introduction of interventions A-D for patients and staff affected, and days of disruption (Figure 2). The number of affected patients fell by 92%, affected staff by 81% and the days of disruption by 88% (Table 2) between April 2010 and March 2014. Additionally, there were six instances of re-infection in a ward within seven days from April 2007 to March 2010, but none between April 2010 and March 2014.

The combined introduction of interventions A ('Stop the Bugs') and B (the care/control bundle) was followed by significant falls in all outcome metrics. IRRs [95% CIs] for the comparison 2008/09 vs. 2007/08 were: outbreaks 0.527 [0.341-0.814]; affected patients 0.466 [0.404-0.537]; affected staff 0.461 [0.317-0.670] and days of disruption 0.388 [0.326-0.461]. The opening of additional side rooms (intervention C) was not followed by a significant fall in outbreaks or affected staff, although reductions in the number of affected patients and days of disruption were significant. IRRs [95% CIs] for the comparison 2009/10 vs. 2008/09 were: outbreaks 0.677 [0.389-1.179]; affected patients 0.773 [0.648-0.923]; affected staff 1.350 [0.897-2.032] and days of disruption 0.633 [0.499-0.802]. The greatest reductions were seen after the introduction of intervention D (IPC Manager). IRRs [95% CIs] for the comparison of the mean for 2009/14 vs. 2009/10 were: outbreaks 0.095 [0.042-0.215]; affected

patients 0.080 [0.061-0.105]; affected staff 0.185 [0.045-0.769] and days of disruption 0.116 [0.039-0.349].

(C) Bed occupancy

Bed occupancy increased from 81.1% to 91.2% over the study period (Table 2).

DISCUSSION

In comparison to other hospitals, and despite increasing bed occupancy, PHT experienced a sustained reduction in hospital-acquired norovirus outbreaks after introducing a QI initiative, which commenced in 2008. Outbreaks were reduced by over 60% between 2007/08 and 2009/10, coinciding with the introduction of interventions A-C. In particular, the combined introduction of interventions A ('Stop the Bugs') and B (the care/control bundle) led to significant falls in all outcome metrics. However, in 2009/10, there were still 21 outbreaks, affecting 218 patients and 54 staff, and leading to 112 days disruption. Early recognition of index patients remained difficult and, by the time they were reported, outbreaks typically already involved several patients, and had been in progress for >24h.

In April 2010, IPC Manager (intervention D) was introduced in order to reduce the time from a patient's first symptoms to the IPCT becoming aware and commencing proactive interventions. Its introduction was associated with an abrupt and sustained reduction in norovirus outbreaks, affected patients, affected staff and days of disruption in the following four years. Instances of re-infection disappeared.

Following IPC Manager's introduction, PHT experienced few winter bed closures due to norovirus-like symptoms; quite different to the experience of other study hospitals. Although not measured, the implied patient benefit – less patient distress and discomfort; fewer severe or fatal complications[23-25] – and the estimated financial savings resulting from reduced treatment needs and length of stay[10-12] will have been significant.

This study has several strengths. It uses national definitions for defining outbreaks and data come from national reporting schemes. Positive laboratory report and outbreak data for Wessex and England were obtained via PHE's optional HNORS, but SITREP data are mandatory national returns and are likely to

be reliable. Indeed, if anything, laboratory, outbreak and SITREP figures are an underestimate, as over-report of outbreaks is unlikely. The observed sustained outbreak reduction at PHT has a plausible direct relationship to the interventions. Importantly, outbreak incidence was reduced at PHT compared to immediately local hospitals (i.e., Wessex), suggesting a hospital-specific effect. Finally, the work was done during a period in which norovirus activity appears to be increasing.[26,27]

However, there are also weaknesses. It is a single-centre, retrospective study: similar results might not be replicated elsewhere. Interventions were not introduced in a controlled manner, making identification and quantification of individual and relative influences on outbreak reduction difficult. HNORS data reporting is optional and hospitals need not make a zero return, making it impossible for us to produce 'per hospital' outbreak figures for Wessex and England. Another possible confounder is the random variation in annual norovirus outbreaks.[20]

The QI measures that were introduced focus on: (1) staff, patient and visitor education regarding norovirus and preventing spread; (2) accurate timely bedside recording of patients' physiology and symptoms; (3) early availability of data facilitating prompt outbreak recognition; (4) automatic and real-time notification of high-risk patients to the IPCT; and (5) early IPCT intervention with effective infection control measures. None of these components would be sufficient alone to reduce outbreaks to the extent that we observed. However, with all other necessary interventions deployed, we postulate that IPC Manager provided the final link necessary to prevention infection spread (i.e., early and focused identification of index cases).

As noroviruses are highly contagious and have a short incubation period, and patients are most contagious when symptomatic,[28] the ability to identify index patients as soon as possible after symptoms occur is crucial. IPC Manager facilitated rapid mobilization of the IPCT (much earlier than via 'usual' communication routes), enabling implementation of effective isolation and suppression measures, the prevention of cross-infection of patients, staff and visitors, and the avoidance of outbreaks.

Nevertheless, IPC Manager is unlikely to have worked without other important QI changes. Considerable effort was made to dispel the belief that norovirus outbreaks are inevitable, and to

educate staff, patients and visitors about the causes and prevention of norovirus infection, and the need for improved social behaviour. These helped to create a common purpose of eliminating norovirus infection, which was supported by the hospital board, clinical governance committee and IPCT, who emphasised commitment to following evidence-based, national guidance on eliminating norovirus and other healthcare associated infections (HCAI). The PHT and TLC staff that designed and developed both VitalPAC and IPC Manager provided further innovative leadership. The IPCT showed commitment to monitoring of clinical practice (e.g. regular hand-hygiene audits) and outcomes at ward level (i.e., norovirus 'attack' rates), and to disseminating the results. The increased IPCT presence on wards also demonstrated their direct engagement in the initiative to reduce HCAIs.

One QI intervention – additional side rooms and increased bed space[29] (intervention C) – did not result in a significant independent fall in outbreaks or affected staff, although affected patients and days of disruption were reduced. This is probably because moving infected patients to side rooms would necessarily reduce the number of days of ward closure, but could not affect the speed of reporting new cases to the IPCT. Similarly, although the other interventions implemented before winter 2009/2010 had a significant impact on all outcome metrics, outbreaks still occurred presumably because they failed to speed up the recognition of index patients.

This study re-emphasises the power of suitably designed IT systems to facilitate improved clinical outcomes.[17] Internet surveillance has been proposed for monitoring infectious disease outbreaks and electronic surveillance of HCAI is increasing.[4,30.31] However, we believe that our report is the first to show reductions in infectious disease following the use of real-time focused alerts sent directly to a hospital IPCT using routinely available clinical and laboratory data.

In summary, nosocomial outbreaks of suspected/confirmed norovirus have virtually been eliminated at PHT, despite evidence that outbreaks remain a regular problem for many regional and national hospitals. This appears to result from combined interventions focused on education, monitoring, early automated recognition and notification of infection of index patients, and a prompt response using robust infection control measures by the IPCT. Whilst impossible to prove a direct cause-and-effect relationship with any individual intervention, there are strong plausible temporal relationships between the outbreak reduction, and the events at hospital level.

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LEGENDS FOR FIGURES

Figure 1:

Mean weekly numbers of closed beds at PHT; the eight acute Trusts in the former NHS South Central Strategic Health Authority [SHA Q38]; and all 158 acute Trusts in England because of norovirus, as reported via Daily Winter Pressures Situation Reports (SITREPs) during winter periods 2010/11, 2011/12, 2012/13 and 2013/14. Study weeks refer to fiscal weeks

Figure 2:

Impact of norovirus outbreaks at PHT, showing the annual number of outbreaks; affected patients; affected staff and days of disruption for the period April to March for the years 2007/08 to

2013/14. The duration of disruption was defined as the number of days during which a clinical area was 'closed' or under 'special' infection control measures. A = 'Stop the Bugs' campaign; B = Targeted norovirus care and control bundle; C = New hospital block opened; D = Infection Prevention & Control Manager (IPC Manager) implemented.

Supplementary Figure 1:

Number of monthly suspected/confirmed norovirus outbreaks for the period 1st September 2006 to 31st May 2014 for PHT obtained from Infection and Prevention Control Team records, with major infection control interventions marked. A = 'Stop the Bugs' campaign; B = Targeted norovirus care and control bundle; C = New hospital block opened; D = Infection Prevention & Control Manager (IPC Manager) implemented. The outbreak duration was defined as the period (days) from onset to completion. Outbreaks were considered over when there had been no new cases for seven days in the clinical area.

Supplementary Figure 2:

Number of monthly suspected/confirmed norovirus outbreaks (1st January 2009 to 31st May 2014) obtained from Public Health England for the Wessex group of seven acute hospitals and four community Trusts that manage hospitals. The outbreak duration was defined as the period (days) from onset to completion. Outbreaks were considered over when there had been no new cases for seven days in the clinical area.

Supplementary Figure 3:

Number of monthly suspected/confirmed norovirus outbreaks (1st January 2009 to 31st May 2014) obtained from Public Health England for the hospitals and community settings in England. The outbreak duration was defined as the period (days) from onset to completion. Outbreaks were considered over when there had been no new cases for seven days in the clinical area.

APPENDIX 1: ELEVEN HEALTH PROVIDERS IN THE WESSEX REGION - SEVEN ACUTE NHS TRUSTS AND NHS FOUNDATION TRUSTS

1. Portsmouth Hospitals NHS Trust (PHT)
2. Royal Bournemouth & Christchurch Hospitals NHS Foundation Trust
3. University Hospital Southampton NHS Foundation Trust
4. Poole Hospital NHS Foundation Trust
5. Dorset County Hospital NHS Foundation Trust
6. Hampshire Hospitals NHS Foundation Trust
7. Isle Of Wight NHS Trust
8. Southern Health NHS Foundation Trust
9. Dorset Healthcare University NHS Foundation Trust
10. Isle Of Wight NHS Primary Care Trust
11. Solent NHS Trust

APPENDIX 2: EIGHT ACUTE NHS TRUSTS AND NHS FOUNDATION TRUSTS IN THE NHS SOUTH CENTRAL STRATEGIC HEALTH AUTHORITY (SCSHA), OTHER THAN PORTSMOUTH HOSPITALS NHS TRUST

1. Isle of Wight NHS Trust
2. Heatherwood and Wexham Park Hospitals NHS Foundation Trust
3. Milton Keynes Hospital NHS Trust
4. University Hospital Southampton NHS Foundation Trust
5. Royal Berkshire NHS Foundation Trust
6. Hampshire Hospitals NHS Foundation Trust
7. Oxford University Hospitals NHS Trust
8. Buckinghamshire Healthcare NHS Trust

Figure 1

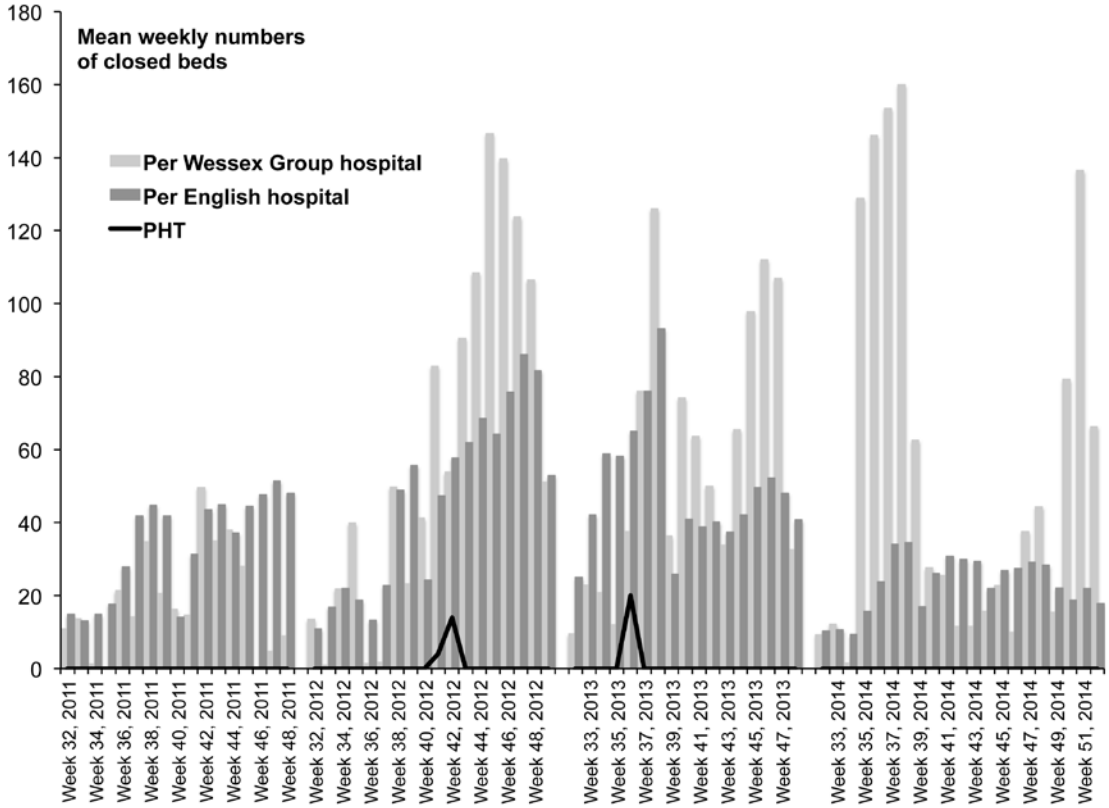
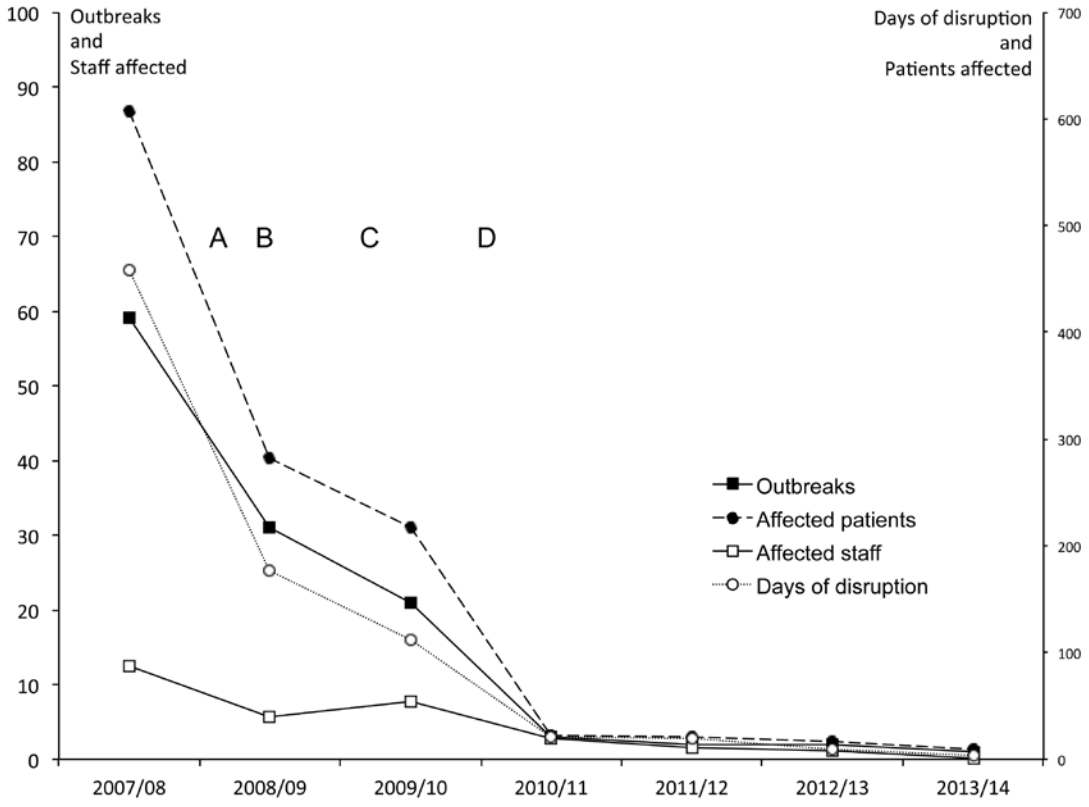
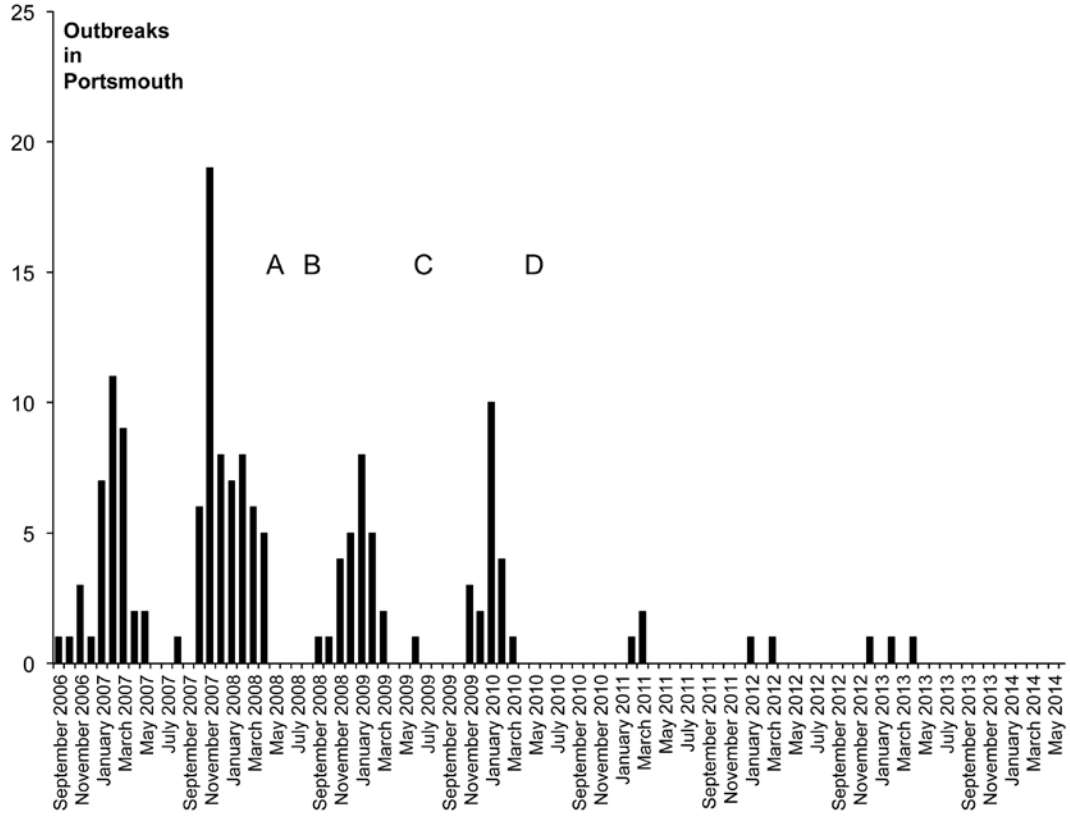

Mean weekly numbers of closed beds
Per Wessex Group hospital
Per English hospital
PHT
180
160
140
120
100
80
60
40
20
0
Week 32, 2011
Week 34, 2011
Week 36, 2011
Week 38, 2011
Week 40, 2011
Week 42, 2011
Week 44, 2011
Week 46, 2011
Week 48, 2011
Week 32, 2012
Week 34, 2012
Week 36, 2012
Week 38, 2012
Week 40, 2012
Week 42, 2012
Week 44, 2012
Week 46, 2012
Week 48, 2012
Week 33, 2013
Week 35, 2013
Week 37, 2013
Week 39, 2013
Week 41, 2013
Week 43, 2013
Week 45, 2013
Week 47, 2013
Week 33, 2014
Week 35, 2014
Week 37, 2014
Week 39, 2014
Week 41, 2014
Week 43, 2014
Week 45, 2014
Week 47, 2014
Week 49, 2014
Week 51, 2014

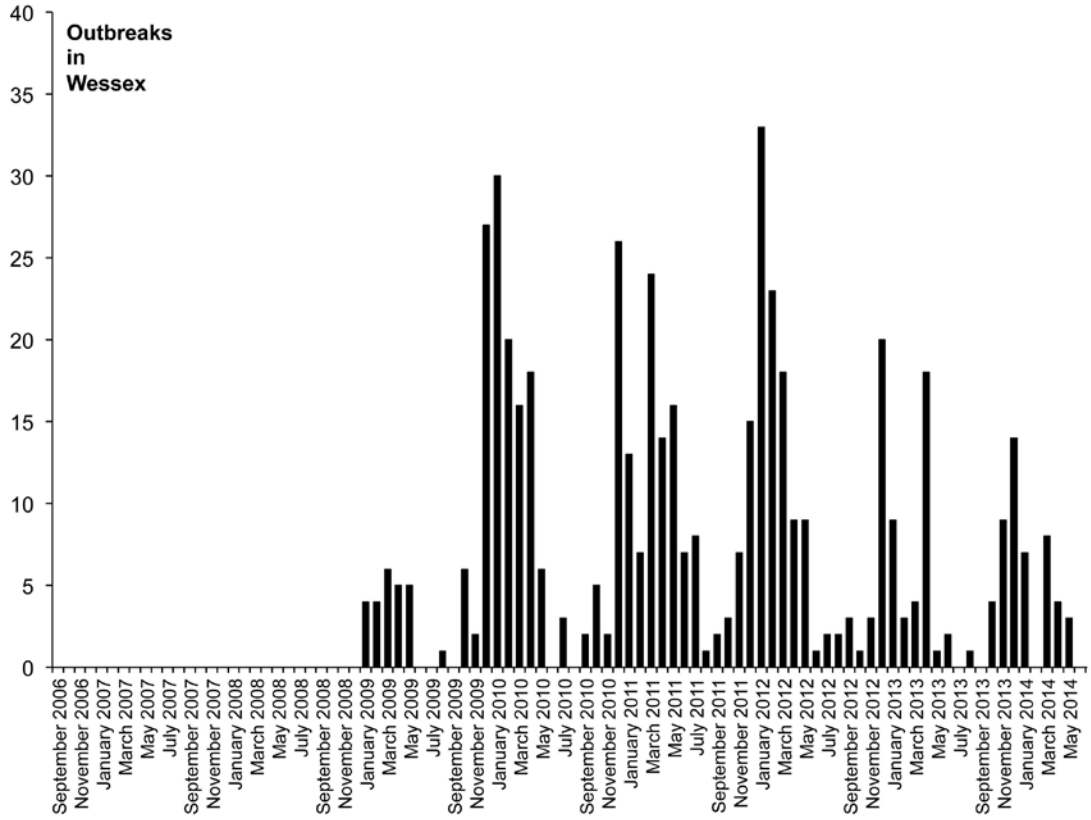
Figure 2


Outbreaks
and
Staff affected
Days of disruption
and
Patients affected
100
90
80
70
60
50
40
30
20
10
0
700
600
500
400
300
200
100
0
A
B
C
D
Outbreaks
Affected patients
Affected staff
Days of disruption
2007/08
2008/09
2009/10
2010/11
2011/12
2012/13
2013/14

Supplementary Figure 1



Supplementary Figure 2



Supplementary Figure 3