Journal of Hospital Infection 90 (2015) 28–37

Available online at www.sciencedirect.com

Journal of Hospital Infection

journal homepage: www.elsevierhealth.com/journals/jhin

Impact of infection control interventions on rates of *Staphylococcus aureus* bacteraemia in National Health Service acute hospitals, East Midlands, UK, using interrupted time-series analysis☆

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ARTICLE INFO

Article history:
Received 20 May 2014
Accepted 24 December 2014
Available online 15 January 2015

Keywords:
Healthcare-associated infection
MRSA
MSSA
Time-series analysis

SUMMARY

Background: Reducing healthcare-associated infection (HCAI) is a UK national priority. Multiple national and regional interventions aimed at reduction have been implemented in National Health Service acute hospitals, but assessment of their effectiveness is methodologically challenging.

Aim: To assess the effectiveness of national and regional interventions undertaken between 2004 and 2008 on rates of meticillin-resistant *Staphylococcus aureus* (MRSA) and meticillin-sensitive *Staphylococcus aureus* (MSSA) bacteraemia within acute hospitals in the East Midlands, using interrupted time-series analysis.

Methods: We used segmented regression to compare rates of MRSA and MSSA bacteraemia in the pre-intervention, implementation, and post-intervention phases for combined intervention packages in eight acute hospitals.

Findings: Most of the change in MSSA and MRSA rates occurred during the implementation phase. During this phase, there were significant downward trends in MRSA rates for seven of eight acute hospital groups; in four, this was a steeper quarter-on-quarter decline compared with the pre-intervention phase, and, in one, an upward trend in the pre-intervention phase was reversed. Regarding MSSA, there was a significant positive effect in four hospital groups: one upward trend during the pre-intervention phase was reversed, two upward trends plateaued, and in one hospital group an indeterminate trend decreased significantly. However, there were significant increasing trends in quarterly MSSA rates in four hospital groups during the implementation or post-intervention periods.

☆ Study carried out whilst affiliated with Public Health England, East Midlands.

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http://dx.doi.org/10.1016/j.jhin.2014.12.016

Conclusion: The impact of interventions varied by hospital group but the overall results suggest that national and regional campaigns had a beneficial impact on MRSA and MSSA bacteraemia within the East Midlands.

Introduction

The prevalence of healthcare-associated infections (HCAIs) was 6.4% in English National Health Service (NHS) hospitals during 2011 with estimated treatment costs of approximately £1 billion per year.[1,2] Substantial resources have been devoted towards decreasing the incidence of HCAI in the UK, including, since 2004, the national campaigns: 'Saving Lives', 'Cleanyourhands', 'Clean Safe Care' and 'Deep Clean Programme'; and regional initiatives such as 'Hand in Hand' (2007) in the East Midlands region. These campaigns involved hand hygiene, high-impact patient-level interventions, and improved infection control and awareness (Supplementary Table I).

The evaluation of HCAI interventions has generally been constrained by methodological shortcomings in dealing with multiple, often overlapping interventions and a lack of control sites for national interventions. Nevertheless, it is important that interventions, particularly those that require substantial resources, are evaluated using robust methods. This study used interrupted time-series analysis to assess the impact of national and regional HCAI interventions on rates of meticillin-resistant *Staphylococcus aureus* (MRSA) and meticillin-sensitive *Staphylococcus aureus* (MSSA) bacteraemia in NHS acute hospitals in the East Midlands. NHS acute hospital services are managed by 'acute trusts', organizations that each deliver services to a defined geographical area through one or more acute hospitals. Interrupted time-series analysis is recognized as the strongest quasi-experimental design to evaluate longitudinal effects of an intervention.[3]

Methods

Data sources

Anonymized quarterly counts of MRSA bacteraemia (both hospital- and community-apportioned) from April 2001 to March 2011 for the eight acute NHS trusts (hereafter called 'trusts') in the East Midlands were obtained from mandatory data sets from Public Health England (known during 2004–2013 as the Health Protection Agency, and before 2004 as the Public Health Laboratory Service). Mandatory reporting of MSSA bacteraemia only began in January 2011; therefore numbers of MSSA cases were calculated by subtracting the number of 'blood culture MRSA-positive samples' in quarterly mandatory laboratory returns from total 'blood culture *Staphylococcus aureus*-positive samples'. Bacteraemia counts were converted into time-series of MRSA and MSSA incidence rates per 100,000 bed-days using reported average bed-day activity.[4] Ethical approval was not required as this analysis used only aggregate, anonymized data.

Intervention data

Information on the HCAI interventions implemented in each acute trust and their start dates had been collected previously using detailed questionnaires with trust staff (Supplementary Figure 1).[5] These start dates were used in this study rather than official campaign roll-out dates because actual implementation of national campaigns varied within individual trusts due to local practicalities or involvement in pilot studies. Where discrepant dates were identified which could not be resolved, the earliest start date of the campaign was used to ensure that the earliest possible implementation was captured. The five interventions covered in the study are detailed in Supplementary Table I.

Statistical analysis

The various campaigns were implemented simultaneously or very close together in many trusts, making it difficult to isolate and identify the individual effects of specific campaigns. Therefore, campaigns were evaluated together as a composite intervention package. As in previous analyses, we defined an 'implementation phase' spanning the start date of the first intervention to the start date of the last (fifth) intervention.[3,6] Three trusts either did not implement or did not know the start date for the intervention 'Clean Safe Care', hence only four interventions were included in the analysis for these trusts. For the segmented regression analysis, each time-series was split into three segments: a 'pre-intervention phase', an 'implementation phase' and a 'post-intervention phase'. Segmented regression models were applied to each hospital group for MRSA and MSSA bacteraemia separately, assessing changes in the level and the trend of each segment compared with the segment immediately beforehand. We used non-automated backward elimination using the likelihood ratio test at a significance level of $P < 0.05$ to remove non-significant parameters and build a parsimonious model.[3] An example showing the fitted model for trust A is shown in Supplementary Figure 2. Each model was checked for the presence of autocorrelation by visual inspection of the autocorrelation function of the model residuals, and conducting a Portmanteau test using a significance level of $P < 0.05$. There was no evidence of seasonal autocorrelation in the model residuals. Given the relatively short time-series and limited power to detect autocorrelation, a sensitivity analysis was conducted using Prais–Winsten regression for all models to include an 'AR(1)' term in the model *a priori* to account for non-seasonal autocorrelation. This had no appreciable effect on the results, suggesting that any autocorrelation was appropriately accounted for; therefore these data are not presented here (but are available on request). All analyses were carried out using Stata version 11.2 (Stata Corp., College Station, TX, USA).