

From guidelines to practice: a pharmacist-driven prospective audit and feedback improvement model for peri-operative antibiotic prophylaxis in 34 South African hospitals

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Background: Few data exist on the implementation of process measures to facilitate adherence to peri-operative antibiotic prophylaxis (PAP) guidelines in Africa.

Objectives: To implement an improvement model for PAP utilizing existing resources, in order to achieve a reduction in surgical site infections (SSIs) across a heterogeneous group of 34 urban and rural South African hospitals.

Methods: A pharmacist-driven, prospective audit and feedback strategy involving change management and improvement principles was utilized. This 2.5 year intervention involved a pre-implementation phase to test a PAP guideline and a 'toolkit' at pilot sites. Following antimicrobial stewardship committee and clinician endorsement, the model was introduced in all institutions and a survey of baseline SSI and compliance rates with four process measures (antibiotic choice, dose, administration time and duration) was performed. The post-implementation phase involved audit, intervention and monthly feedback to facilitate improvements in compliance.

Results: For 70 weeks of standardized measurements and feedback, 24 206 surgical cases were reviewed. There was a significant improvement in compliance with all process measures (composite compliance) from 66.8% (95% CI 64.8–68.7) to 83.3% (95% CI 80.8–85.8), representing a 24.7% increase ($P < 0.0001$). The SSI rate decreased by 19.7% from a mean group rate of 2.46 (95% CI 2.18–2.73) pre-intervention to 1.97 post-intervention (95% CI 1.79–2.15) ($P = 0.0029$).

Conclusions: The implementation of process improvement initiatives and principles targeted to institutional needs utilizing pharmacists can effectively improve PAP guideline compliance and sustainable patient outcomes.

Introduction

Surgical site infections (SSIs) account for 14%–16% of all hospital-acquired infections and occur in 2%–5% of patients after clean extra-abdominal operations and in up to 20% of patients undergoing intra-abdominal procedures.^{1,2} Patients who develop SSIs are up to 60% more likely to be admitted to the ICU, five times more likely to be readmitted to hospital and twice as likely to die relative to uninfected surgical patients.^{2,3} In addition, healthcare costs are substantially increased for patients who develop SSIs.^{2,3} Thus for those patients who require surgery, the prevention of infection is a major objective in the

provision of effective healthcare and the implementation of evidence-based peri-operative antibiotic prophylaxis (PAP) guidelines is critical to achieving this.

Of note, although the principles of PAP are clearly established and have been shown to be effective, global adherence to these guidelines is generally poor.^{1,4,5} In fact, recent reviews and studies have demonstrated non-compliance in up to 88% of surgical cases.^{4,6,7} The reasons for non-adherence appear to be complex and multifactorial and include fears of litigation, lack of clinician awareness of updated guidelines, lack of enforceable policies, and failures in the implementation of institutional norms, guidelines and patient care systems.^{4,6} In response, various stewardship

interventions have been implemented with the aim of improving adherence to such guidelines and whereas these have included clinician-focused interventions, accumulating evidence suggests that educational interventions are mostly ineffective and result in insignificant changes to overall compliance.⁸

It is possible that this might relate to cognitive dissonance, a process in which clinician-focused education fails to engage prescribers effectively, allowing them to ignore the evidence and to continue with their regular habits and practices.^{8,9} In addition, some of Hofstede's cultural constructs, such as power distance and uncertainty avoidance, have been correlated to inappropriate duration of surgical prophylaxis particularly where antibiotics are prescribed for longer than 24 h.^{10,11} Hence, it appears that it is a challenge to disseminate evidence-based PAP measures systematically into clinical practice.⁶ Alternative strategies to significantly improve adherence to evidence-based measures are required. These may include guidance of clinicians in the institutional process of improvement which has not as yet been addressed in prophylaxis guidelines.

Recent systematic reviews have highlighted that the risk of SSIs is strikingly higher in sub-Saharan Africa than in high-income countries.^{12,13} In contrast, very few data are available on the implementation of, and adherence to, PAP measures.¹⁴ High-quality, comprehensive information to facilitate the development, implementation and monitoring of peri-operative antibiotic interventions as well as outcome measures in low-resource settings are thus warranted. The aims of this study were, therefore, to promote multidisciplinary, collaborative action across a diverse group of 34 urban and rural South African hospitals, firstly with regard to implementation of a non-specialized, pharmacist-driven audit and feedback improvement model for PAP, and secondly to achieve a sustainable reduction in SSIs.

Methods

Setting

The pharmacist-driven improvement initiative for peri-operative antibiotic management was implemented in 34 private hospitals in seven of nine South African provinces operated by the hospital group Netcare Ltd. The participating institutions have in total 7485 registered beds and include 276 operating theatres/suites. In contrast to the surgeons ($n = 132$) and anaesthetists (182), the pharmacists involved in the study ($n = 42$) as well as the infection prevention practitioners (IPPs) and all other nurses are employees of the hospitals. The study covered a 2.5 year period between 1 March 2013 and 1 September 2015. Multidisciplinary antimicrobial stewardship teams existed prior to implementation of the study but did not necessarily involve surgeons, anaesthetists, theatre managers, or peri-operative and surgical ward nurses.

Ethics

The model was approved by the Management Executive, and ethics approval was obtained from Pharma-ethics (reg. no. 160413718)

Study design

Pre-implementation phase (1 March 2013–30 April 2014)

This phase was initiated under the guidance of the quality improvement (QI) director and an antimicrobial stewardship (AMS) project manager as well as local experts (clinical microbiologists and surgeons), and involved

achieving consensus on a PAP guideline for adults, specifically for Netcare Hospitals (Tables S1 and S2, available as Supplementary data at JAC Online) as well as defining four PAP process measures and indicators (Table 1) according to local and international guidelines and best practice and adapted to the South African setting.^{15,16} Following AMS committee endorsement, the model was introduced to relevant clinicians and nurses through institutional workshops, and a 4 week survey of pre-intervention compliance rates with the process measures was performed. The key components critical to the pre-implementation phase of the model are summarized in Table 2 and further detail is provided below. No incentives for pharmacist participation were provided.

Post-implementation phase (1 May 2014–1 September 2015)

This phase commenced with the completion of the pre-intervention recording of compliance with the four process measures. The key components critical to the post-implementation phase of the model are summarized in Table 2. Individualized, hospital-specific goals to improve compliance were continuously revised and feedback provided to each institution as described in Table 2. Feedback of the SSI rate was not provided.

QI model for PAP

The initiative was implemented using a Netcare adaptation of the Institute for Healthcare Improvement (IHI) Model¹⁷ and the Breakthrough Series Collaborative,¹⁸ the details of which were recently published.¹⁹

Briefly, under the executive control of the QI director and AMS project manager based at the head office in Johannesburg, initial training sessions detailing the Netcare PAP guideline (Tables S1 and S2) and the core measures and indicators chosen for improvement (Table 1) were provided through face-to-face regional learning sessions with pharmacists and pharmacy managers from each of the hospitals (learning cycle 1). This group in turn enrolled and trained multidisciplinary antibiotic management teams consisting of surgeons, anaesthetists, hospital, nursing and theatre managers, and peri-operative and surgical ward nurses, including IPPs. The multidisciplinary teams had to choose at least one or more surgical procedures to audit depending on circumstances and the resources of each institution. Thereafter, in accordance with the Netcare model,¹⁹ each pharmacist was required to undertake a stepwise implementation process in their hospital by auditing the four measures for the chosen surgical procedure(s) in hospitalized patients receiving PAP. Subsequently, learning cycles hosted by the QI director and the AMS project manager were held at 8–10 week intervals initially and once the model was entrenched as needed, either via national teleconferencing with pharmacists and pharmacy managers or through face-to-face hospital (pending the need for on-site assistance) and regional workshops.

Process measures and indicators

For all measures (such as stopping antibiotics after 24 h), the frontline doctor (anaesthetist and/or surgeon) was consulted before changes were effected by the pharmacists. This was done verbally or by written or mobile phone messages. Similarly, if antibiotic choice, dose, timing and redosing was inappropriate, it was communicated to the relevant multidisciplinary teams. Compliance with weight-based dosing was audited for cefazolin (25–30 mg/kg) only in patients <60 kg or >80 kg, in addition to all patients receiving gentamicin (5–7 mg/kg) and vancomycin (15 mg/kg) (Tables S1 and S2). Pharmacists were not able to make changes to prescriptions themselves either for antibiotic choice or dose.

Parenteral PAP use was audited in patients ≥ 18 years who had indications for PAP (Tables S1 and S2). Oral or topical prophylactic antibiotics were

Table 1. Core measures and indicators for audit in the Netcare PAP improvement model

	Measures	Indicators
	Process measures	
1	Antibiotic choice: was the antibiotic chosen compliant with the Netcare guideline for that procedure? in patients with β -lactam allergies, was the chosen alternative compliant with the Netcare guideline?	rate of compliance with antibiotic choice relative to the surgery type or with the alternative agent
2	Antibiotic dosage: a. was the prescribed dose of the antibiotic consistent with the Netcare guideline? b. in case of cefazolin, gentamicin and vancomycin, was weight-based dosing compliant with the Netcare guideline?	rate of compliance with the antibiotic dose or with weight-based dosing where indicated
3	Antibiotic administration: ^a was the antibiotic administered within 60 min prior to surgery?	rate of compliance with administration within 60 min
4	Antibiotic duration: ^b a. was the antibiotic administered as a single dose? b. was the antibiotic redosed where applicable? c. was the antibiotic given for >24 h?	rate of compliance with the administration of a single dose or, where applicable, redosed or discontinued within 24 h after initiation of surgery
	Outcome measures	
1	The number of SSIs occurring postoperatively ^c	SSI rate

^aAdministration within 120 min of incision was advised for vancomycin and fluoroquinolones.¹⁵

^bRedosing was acceptable for cases of intraoperative blood loss >1500 mL or procedures greater than 2.5 h long.¹⁵

^cDefined by standard CDC definitions for SSIs.^{20,21}

excluded. Comorbidities (including other patient-level risk data) and compliance with other components of SSI bundles that may have an impact on the incidence of SSIs were not audited or modified in any way. Surgery involving burns management or transplantation was excluded from the study.

Outcome measures and indicators

SSIs occurring post-operatively were recorded independently by the IPPs at each hospital according to standard CDC definitions and classifications, within 30 or 30–90 days for superficial incisional or deep incisional procedures, respectively.^{20,21} For reporting purposes, a composite SSI rate (not specified as superficial incisional, deep incisional or organ/space SSIs) was calculated and reported monthly to the QI director and AMS project leader as described below.

Measuring the impact of the PAP model

Process indicators

The standardized measurements were calculated as percentages relative to the number of surgical patients seen on pharmacy rounds, with the denominator being the number of patients receiving PAP, and the numerator those who were compliant with each of the four process indicators. The rate of compliance with duration of administration included the use of a single dose or, where applicable, a second dose or discontinuation within 24 h after initiation of surgery. Overall compliance with the four process measures was calculated as follows: the sum of the total number of indicators with which the doctors were compliant divided by the total number of indicators ($n=4$). Improvements in compliance with the prophylaxis bundle

were measured by the project manager according to the QI run-chart rules described by Langley *et al.*¹⁷ and Perla *et al.*,²² and feedback was provided to the pharmacists and multidisciplinary teams as described in Table 2.

Outcome indicator

SSI rates per 1000 operative procedures were calculated by dividing the number of SSIs by the number of major surgical procedures performed (defined according to the CDC)^{20,21} and multiplying the result by 1000; these rates were reported monthly by the IPP as described above. The rate of SSIs occurring post-operatively in patients who received inappropriate prophylaxis compared with those who received appropriate prophylaxis was not determined.

Statistical analysis

To assess the pre- versus post-implementation changes in patients receiving appropriate prophylaxis, the mean weekly compliance with the four measures, as well as overall compliance over the 4 weeks pre-implementation, were compared with those over the last 4 weeks of the post-implementation phase using the independent-samples *t*-test. The proportion of patients complying (total number of compliant cases according to each compliance metric divided by the total number of patients) over the same time periods were compared by the *z*-test for proportions. The impact of the improvement model on the mean monthly SSI rate was analysed over 14 months pre-implementation and 16 months post-implementation, respectively, using the independent-samples *t*-test. Data analysis was carried out using SAS version 9.4 for Windows. The 5% significance level was used.

Table 2. Key components of the two phases of the Netcare PAP improvement model

Pre-implementation phase

- 1 Record SSI rate by the IPPs at each hospital and report monthly to the QI director and AMS project leader
- 2 Recruit non-specialized pharmacists who wish to develop stewardship skills (voluntary)
- 3 Develop a PAP 'toolkit' consisting of a standardized template using Microsoft Excel® to facilitate uniform process measurement and data recording
- 4 Test and revise the PAP guideline and toolkit at pilot sites by pharmacists and multidisciplinary teams^a
- 5 Launch PAP guideline and toolkit to all pharmacists and multidisciplinary teams through regional training and institutional workshops ($n = 34$), respectively
- 6 Obtain consensus and endorsement from doctors, and hospital, pharmacy and nursing management by adapting and modifying PAP guideline/ measures, if applicable^b
- 7 Choose at least one or more surgical procedures to audit depending on circumstances and resources (surgical and pharmacy) of each institution
- 8 Mandate protected pharmacist stewardship time such that one or more of the pharmacists are allowed time, according to the size of the hospital, to conduct audit rounds of patients undergoing surgical procedures
- 9 Record pre-intervention baseline prophylaxis practices and trends of peri-operative antibiotic use for chosen surgery type(s) in each institution by measuring compliance with the four process measures for 4 weeks

Post-implementation phase

- 1 Record PAP indicators weekly on standardized templates and submit monthly via e-mail to the project manager
- 2 AMS project manager to provide feedback to pharmacists and their managers regarding process improvements (or otherwise) and individualized goals (with timelines) in both written (monthly e-mails) and verbal format during learning cycles in order to facilitate multidisciplinary self-monitoring and action planning
- 3 One to three monthly pharmacist feedback on improvements in compliance with the PAP bundle presented to multidisciplinary hospital teams^a in theatre tea rooms, sent via e-mail to the surgeons and anaesthetists and/or presented during journal clubs (if applicable) and AMS committee meetings
- 4 Stimulate further improvement by providing feedback on progress of the initiative and its effects on compliance via monthly e-mails to all hospitals in the form of comparative tables and graphs

^aMultidisciplinary teams consisted of surgeons and anaesthetists, hospital-, pharmacy-, nursing- and theatre-managers, pharmacists, and peri-operative and surgical ward nurses including IPPs.

^bAn open invitation by the QI director and AMS project leader.

Results

The mean compliance and mean SSI rate for 34 hospitals over the two phases of the PAP improvement model are depicted in Figures 1 and 2, respectively.

Pre-implementation phase (1 March 2013–30 April 2014)

In this phase 6/34 hospitals volunteered to test the QI model. The Netcare PAP guideline and standardized measurement toolkit was revised seven times after consultation with all the multidisciplinary teams ($n = 34$), which included surgeons and anaesthetists. Pre-intervention measurement of the rate of compliance over 4 weeks revealed the following (Figure 1). An antimicrobial was administered to 34.7% (95% CI 31.7–37.7) of patients within 1 h before incision. Antimicrobial agents consistent with the guideline were administered to 81.2% (95% CI 78.5–83.8) of the patients and at the recommended dose in 70.5% (95% CI 67.1–73.9). Antimicrobial prophylaxis was limited to one dose or discontinued within 24 h of the end of surgery in 80.8% (95% CI 79.0–82.5) of patients. Thus the pre-intervention survey of compliance with all four key measures revealed a composite compliance rate of 66.8%

(95% CI 64.8–68.7). During this phase the mean SSI rate for the hospital group was 2.46 (95% CI 2.18–2.73).

Post-implementation phase (1 May 2014–1 September 2015)

In this phase the model was embedded in existing practice, with daily auditing of the four targets chosen for improvement for the selected surgical procedures becoming standard practice for those patients receiving peri-operative antibiotics. Twenty-one learning cycles were held. Benchmarking, by means of comparative tables and multiple graphs describing the success or otherwise of each hospital or region, led to competitiveness amongst both pharmacists and doctors. During this phase no systematic changes in the types of surgical procedures took place compared with the pre-implementation phase, and similarly there were no changes in use of other components of SSI bundles.

Fifty percent (17/34) of the hospitals chose to audit only one surgical procedure, 26% (9/34) audited two, 15% (5/34) three and 9% (3/34) four. None of the multidisciplinary teams chose procedures classified as contaminated or dirty/infected. For 70 weeks of standardized measurement and feedback, 24 206 surgical cases were reviewed, with obstetric and gynaecological ($n = 24$) and

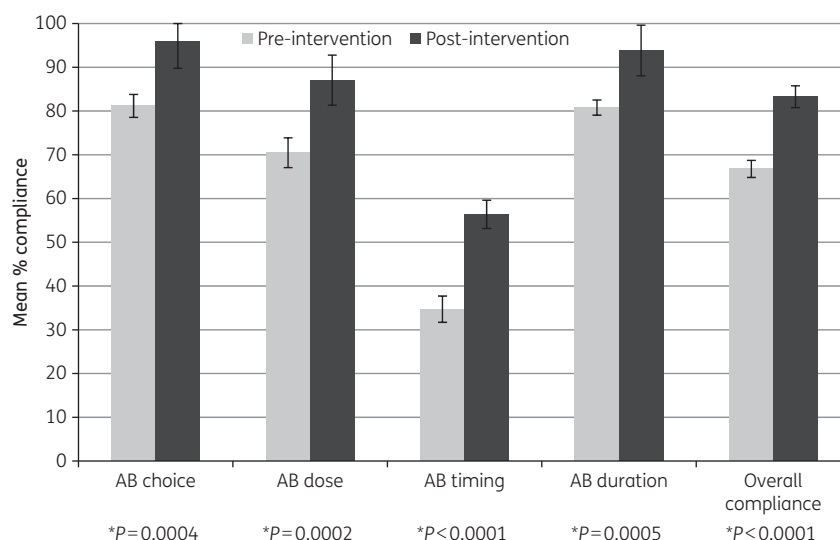


Figure 1. Mean rate of compliance with the process measures during the pre- and post-implementation phases of the Netcare PAP improvement model ($n = 34$ hospitals). The error bars denote the 95% CI for the mean. An asterisk denotes a statistically significant difference in mean compliance between 4 weeks pre-implementation and the last 4 weeks post-implementation. AB, antibiotic.

orthopaedic ($n = 22$) the most common types of surgery audited, followed by cardiovascular, thoracic and other vascular surgery ($n = 5$), neurosurgery ($n = 3$) and gastrointestinal surgery ($n = 2$). Plastic surgery related to breast cancer and urological surgery was audited by only two hospitals.

Compared with the pre-implementation phase, there was a significant increase in compliance with all process measures during the last four weeks of the study (Figure 1). Timely administration occurred in 56.4% (95% CI 53.1–59.6) ($P < 0.0001$), antibiotic choice consistent with the guideline was administered in 95.9% (95% CI 89.9–100) ($P = 0.0004$), at the recommended dose in 87.0% (95% CI 81.3–92.8) ($P = 0.0002$) and the duration of PAP was appropriate for 93.9% (95% CI 88.1–99.6) ($P = 0.0005$). This represented an increase in the rate of compliance for each of the indicators of 62.4%, 18.1%, 23.5% and 16.2%, respectively. Considering the proportion of compliant cases, for each of the four individual measures these were also found to have increased significantly from pre- to post-intervention ($P < 0.0001$ in all cases).

Overall compliance increased 24.7% to a group mean of 83.3% (95% CI 80.8–85.8) ($P < 0.0001$). Concurrently, a sustained decrease in the SSI rate of 19.7% to a mean rate of 1.97 (95% CI 1.79–2.15) ($P = 0.0029$) was observed (Figure 2). If the timing indicator was excluded, the overall rate of compliance was 92.26%.

Discussion

This multicentre antimicrobial stewardship initiative, led by non-specialized pharmacists, significantly improved adherence to a PAP bundle which in turn led to a significant reduction in SSI rates across a large network of diverse urban and rural hospitals in South Africa. Whilst studies elsewhere have demonstrated that global adherence to PAP guidelines is generally poor, and that clinician-focused education fails to lead to substantial changes in overall compliance with evidence-based measures, the fact is that prophylaxis guidelines offer limited guidance to clinicians on how to actually improve care.²³

It is possible that, as has been demonstrated in this study, the answer may lie within the principles and imperatives contained with the change processes in hospitals. The development of effective teams and the coordination of processes according to the Institute of Medicine,²⁴ directed to institutionalizing new approaches according to Kotter's 'guiding coalition',²⁵ appear essential to improving peri-operative antibiotic care. Pivotal to our success was engagement with the clinicians, and involvement of theatre managers and anaesthetic, peri-operative and surgical ward nurses and their support for the process of change.

We and others have previously shown that a multidisciplinary collaborative team approach and the use of process improvement principles to accelerate the process of change significantly improved various aspects of antibiotic management and, in particular, reduced 'hang-time',²⁶ curtailed excessive use¹⁹ or streamlined PAP processes.^{23,27} This approach decreases variability in antibiotic management whilst embedding stewardship interventions and 'best practice' in existing systems. In addition, coordination and interdisciplinary engagement in our stewardship programme across a large health system by non-specialized pharmacists in South Africa were previously shown to be key.^{19,26}

There is only limited research available from sub-Saharan Africa on the efficacy of interventions to curb the occurrence of SSIs¹⁴ and except for a single-centre but dissimilar study that involved the introduction of a prophylaxis policy in Kenya,²⁸ none is suitable against which to benchmark our PAP intervention. Instead, our pre-intervention evaluation of compliance with PAP measures somewhat mirrors that published in 2005 by Bratzler *et al.*²⁹ in a systematic random sample of 34 133 Medicare inpatients in 2965 acute care hospitals in the USA prior to introduction of the Surgical Care Improvement Program (SCIP).

Prior to implementation of our model we found inconsistencies in antibiotic choice, dose and duration and particularly the timing of administration, indicating that substantial improvement opportunities existed. Recent evidence suggests that none of the individual measures is significantly associated with a lower probability of

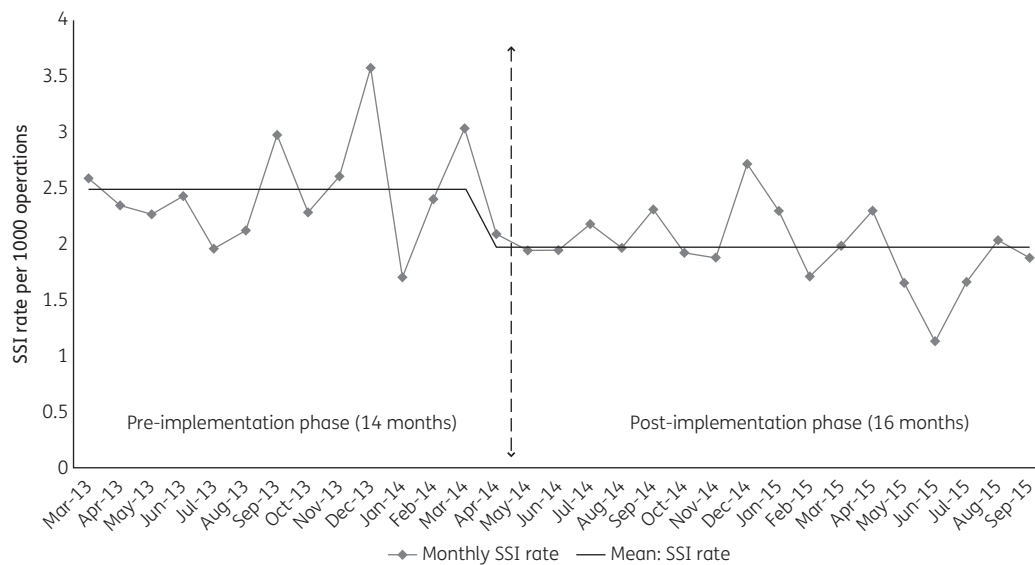


Figure 2. Mean monthly SSI rate during the pre- and post-implementation phases of the Netcare PAP model ($n = 34$ hospitals).

infection. Compliance with timing, stratified by procedure type, is specifically not closely linked with the occurrence of SSI in any population.^{7,30,31} It appears that adherence, measured through a global all-or-none composite measure of compliance does lead to a significant reduction in SSIs particularly if it includes additional bundle measures such as glucose control, appropriate surgical site hair removal and post-operative normothermia.³⁰

Although significant improvements in all the measures were documented, the low overall non-compliance with the timing measure warrants closer attention. In this regard, our model led to 92% compliance with the clinician-dependent measures (antibiotic choice, dose and duration) but not for the institutional-dependent timing measure, where despite a 62.4% increase in timely administration relative to the pre-implementation phase, at the end of the study this occurred in only 56.4% of cases. However, during on-site visits by the AMS project manager (external audit), it was apparent that most patients did receive antibiotics within the required time frame, but the lack of an explicitly documented incision time was the cause of the non-compliance in the majority of cases (data not shown).

The collaborative learning process during audit and feedback, to enable self-monitoring and provision of action plans, resulted in various institutional changes in the delivery of the antibiotics which enhanced the stewardship initiative. These included, amongst others, making infusions available at the patient's bedside, either in the ward or in theatre prior to induction, utilization of prompts and reminders on patient and theatre files, as well as anaesthetists eventually accepting responsibility and accountability for insertion of intravenous lines and for administration of antibiotics. In addition, central to timing non-compliance was the logistical impact of admitting elective cases on the same day as the surgery which was a mandated hospital or medical insurance requirement as a result of cost restrictions as well as quick theatre turnaround times. As the PAP initiative is ongoing, these processes have been addressed and substantial improvements in the timing indicator have subsequently been maintained.

In any event, failure to comply with the timing measure reflects the presence of poorly designed and inefficient delivery systems universal to most healthcare settings²⁴ rather than cognitive deficits or individual negligence on the part of the healthcare workers. Our study emphasizes that changes in institutional delivery are critical to successful stewardship initiatives and that the fundamentals of drug delivery in a hospital setting are as important as clinician-dependent measures if we are to improve patient care.

Study limitations

As highlighted by Dellinger *et al.*,²⁷ analysis of our results is confounded by a number of limiting factors that are typical of a collaborative intervention not present in single-centre initiatives. Participating hospitals were free to select the type of operation(s) targeted for improvement, and as a consequence of local context and surgical resources the selection varied widely not only in the type of surgery but in the numbers audited. Because the expected SSI rates for various clean or contaminated procedures also vary widely, it was not possible to utilize and compare the SSI rate of one hospital or region with another or to use this to stimulate further improvements in practice. We could only use comparisons in process improvement to trigger change amongst pharmacists and clinicians in the multidisciplinary teams. This also implies that the effect of each specific intervention on the SSI rate could not be measured.

Another limitation relates to the fact that only parenteral PAP use was audited for the chosen procedures where prophylaxis was indicated according to our guideline. We therefore lack information regarding the overall rate of inappropriate or incorrect use of PAP for all procedures performed in our network. Furthermore, although protected pharmacist stewardship time was mandated to facilitate auditing rounds, pharmacists were—due to time constraints—nevertheless not required to record and report the presence or absence of patient-level risk data that could be used for risk adjustment between institutions. We do not believe, however,

that changes in the case mix account for the improvements in the measures that were seen, because each pharmacist was reporting data for the same types of operations in one institution.

Conclusions

Our study demonstrates that collaborative implementation of process improvement initiatives and principles are effective in bridging the gap between clinician guidelines and improvement in care and outcomes in surgical patients. Embedding the improvement initiative in routine practice and involving peri-operative, anaesthetic and surgical ward nurses was vital to achieving a sustainable benefit.

There are unique challenges specific to smaller and rural hospitals particularly in settings with limited resources which may hamper the ability to implement appropriate PAP measures. Thus an important question relates to whether the intervention would also work in the public sector where the majority of the South African population receive healthcare. In this regard, successful surgical improvement interventions have been implemented in a variety of other non-academic settings,²⁷ including low-resource countries such as Colombia,²³ and these initiatives and studies such as ours are instructive. We therefore contend that this improvement initiative may be of value in this setting, or for that matter in any urban, rural or small hospital regardless of a lack of resources and expertise. It would, however, require leadership commitment from all quarters—governmental, hospital and clinical—to acknowledge and support the cardinal role played by non-specialized pharmacists in recruiting multidisciplinary teams and in coordinating interdisciplinary clinician and nurse engagement in such an AMS intervention, which was key to our success.

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We acknowledge the invaluable contribution of all multidisciplinary antibiotic management teams; doctors, clinical microbiologists, pharmacists, nurses including IPPs, hospital, nursing, theatre and pharmacy managers, other members of the Netcare Antimicrobial Stewardship Study Alliance (see the Supplementary data available at JAC Online) as well as Head Office executives for supporting the initiative.

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This study was part of routine improvement interventions of the Netcare hospital group.

Transparency declarations

None to declare.

Supplementary data

Tables S1 and S2, and a list of Netcare Antimicrobial Stewardship Study Alliance members are available as Supplementary data at JAC Online (<http://jac.oxfordjournals.org/>).

References

- Zweigner J, Magiorakos A, Haag L *et al.* *Systematic Review and Evidence-Based Guidance on Perioperative Antibiotic Prophylaxis*. Stockholm: ECDC, 2013. <http://ecdc.europa.eu/en/publications/Publications/Perioperative%20antibiotic%20prophylaxis%20-%20June%202013.pdf>.
- Bratzler DW, Houck PM; for the Surgical Infection Prevention Guidelines Writers Workgroup. Antimicrobial prophylaxis for surgery: an advisory statement from the national surgical infection prevention project. *Clin Infect Dis* 2004; **38**: 1706–15.
- Anthony T, Murray BW, Sum-Ping JT *et al.* Evaluating an evidence-based bundle for preventing surgical site infection. A randomized trial. *Arch Surg* 2011; **146**: 263–9.
- Gouvêa M, de Oliveira Novaes C, Pereira DMT *et al.* Adherence to guidelines for surgical antibiotic prophylaxis: a review. *Braz J Infect Dis* 2015; **19**: 517–24.
- Ansari F, Erntell M, Goossens H *et al.* The European surveillance of antimicrobial consumption (ESAC) point-prevalence survey of antibacterial use in 20 European hospitals in 2006. *Clin Infect Dis* 2009; **49**: 1496–504.
- Tourmousoglou CE, Yiannakopoulou E, Kalapothaki V *et al.* Adherence to guidelines for antibiotic prophylaxis in general surgery: a critical appraisal. *J Antimicrob Chemother* 2008; **61**: 214–8.
- Miliani K, L'Heriteau F, Astagneau P. Non-compliance with recommendations for the practice of antibiotic prophylaxis and risk of surgical site infection: results of a multilevel analysis from the INCISO surveillance network. *J Antimicrob Chemother* 2009; **64**: 1307–15.
- Knox MC, Edye M. Educational antimicrobial stewardship intervention ineffective in changing surgical prophylactic antibiotic prescribing. *Surg Infect (Larchmt)* 2016; **17**: 224–8.
- Gagliardi A, Fenech D, Eskicioglu C *et al.* Factors influencing antibiotic prophylaxis for surgical site infection prevention in general surgery: a review of the literature. *Can J Surg* 2009; **52**: 481–9.
- Cheng AC, Worth LJ. Cultural dimensions relevant to antimicrobial stewardship: the contribution of individualism and power distance to perioperative prescribing practices in European hospitals. *Healthcare Infect* 2015; **20**: 124–7.
- Borg MA. Prolonged perioperative surgical prophylaxis within European hospitals: an exercise in uncertainty avoidance? *J Antimicrob Chemother* 2014; **69**: 1142–4.
- Allegranzi B, Bagheri Nejad S, Combescure C *et al.* Burden of endemic health-care-associated infection in developing countries: systematic review and meta-analysis. *Lancet* 2011; **377**: 228–41.
- Bagheri Nejad S, Allegranzi B, Syed SB *et al.* Health-care-associated infection in Africa: a systematic review. *Bull World Health Organ* 2011; **89**: 757–65.
- Aiken AM, Karuri DM, Wanyoro AK *et al.* Interventional studies for preventing surgical site infections in sub-Saharan Africa - a systematic review. *Int J Surg* 2012; **10**: 242–9. 4
- Najjar PA, Smink DS. Prophylactic antibiotics and prevention of surgical site infections. *Surg Clin North Am* 2015; **95**: 269–83.
- Bratzler DW, Dellinger P, Olsen KM *et al.* Clinical practice guidelines for antimicrobial prophylaxis in surgery. *Am J Health Syst Pharm* 2013; **70**: 195–283.
- Langley GL, Moen R, Nolan KM *et al.* *The Improvement Guide: A Practical Approach to Enhancing Organizational Performance*. 2nd edn. San Francisco, CA: Jossey-Bass Publishers, 2009.
- The Breakthrough Series: IHI's Collaborative Model for Achieving Breakthrough Improvement. *IHI Innovation Series White Paper*. Boston, MA: Institute for Healthcare Improvement, 2003. <http://www.IHI.org>.
- Brink AJ, Messina AP, Feldman C *et al.* Antimicrobial stewardship across 47 South African hospitals: an implementation study. *Lancet Infect Dis* 2016; **16**: 1017–25.

- 20** CDC. *Surgical Site Infection (SSI) Event*. <http://www.cdc.gov/nhsn/PDFs/pscManual/9pscSSICurrent.pdf>.
- 21** Horan TC, Gaynes RP, Martone WJ et al. CDC definitions of nosocomial surgical site infections, 1992: a modification of CDC definitions of surgical wound infections. *Infect Control Hosp Epidemiol* 1992; **13**: 606–8.
- 22** Perla R, Provost L, Murray S. The run chart: a simple analytical tool for learning from variation in healthcare processes. *BMJ Qual Saf* 2011; **20**: 46–51.
- 23** Weinberg M, Fuentes JM, Ruiz AI et al. Reducing infections amongst women undergoing cesarean section in Colombia by means of continuous quality improvement methods. *Arch Intern Med* 2001; **161**: 2357–65.
- 24** Committee on Quality Health Care in America, Institute of Medicine. *Crossing the Quality Chasm: A New Health System for the 21st Century*. Washington, DC: National Academies Press, 2001.
- 25** Kotter JP. Leading change: why transformation efforts fail. *Harvard Business Rev* 1995; **73**: 59–67.
- 26** Messina AP, van den Bergh D, Goff DA. Antimicrobial stewardship with pharmacist intervention improves timeliness of antimicrobials across thirty-three hospitals in South Africa. *Infect Dis Ther* 2015; **4**: S5–S14.
- 27** Dellinger EP, Hausmann SM, Bratzler DW et al. Hospitals collaborate to decrease surgical site infections. *Am J Surg* 2005; **190**: 9–15.
- 28** Aiken AM, Wanyoro AK, Mwangi J et al. Changing use of surgical antibiotic prophylaxis in Thika Hospital, Kenya: a quality improvement intervention with an interrupted time series design. *PLoS One* **8**: e78942.
- 29** Bratzler DW, Houck PM, Richards C et al. Use of antimicrobial prophylaxis for major surgery. *Arch Surg* 2005; **140**: 174–82.
- 30** Stulberg JJ, Delaney CP, Neuhauser DV et al. Adherence to surgical care improvement project measures and the association with postoperative infections. *JAMA* 2010; **303**: 2479–85.
- 31** Hawn MT, Itani KM, Gray SH et al. Association of timely administration of prophylactic antibiotics for major surgical procedures and surgical site infection. *J Am Coll Surg* 2008; **206**: 814–21.