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Using Audit and Feedback and the Benchmark to Enhance Infection Prevention and Control of Multidrug Resistant Organisms: a Quasi-experiment Study

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Research

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Abstract

Background

Infection prevention and control (IPC) is important to prevent the spread of multidrug resistant organisms (MDROs). We aimed to enhance and explore the implementation of preventing and controlling MDROs using audit and feedback and the benchmark.

Methods

This quasi-experimental design was conducted in three hospitals from 1st March 2018 to 30th September 2019. A multimodal intervention treated audit and feedback and benchmark as key components for MDROs IPC was conducted in Wuhan, China. A checklist of 40 implementation indicators based on IPC measures was formed to guide the audit twice a week. Immediate feedback was verbally given after each audit on the spot, and written feedbacks containing benchmark and individual implementation levels were delivered monthly or quarterly in three hospitals. The intervention effect was evaluated by Chi-square and Poisson segmented linear regression. Impacts of implementation of indicators on the incidence were modeled by mixed-effect regressions.

Results

The incidence of nosocomial MDROs decreased by 19.39%, 20.55%, and 24.03% in A, B, and C hospital, respectively. The lowest implementation compliance of indicators was the use of personal protective equipment of doctors (50.24%). The highest was isolated warning signs of nurses (96.46%). The implementation on hand hygiene of doctors (Coef. = -27.87, p=0.001) and nurses (Coef. = -35.44, p=0.001), clean of surrounding instruments and bed unit (Coef. = -4.84, p=0.030), education to patients and relatives (Coef. = -59.51, p=0.031), and sending of specimen inspection timely (Coef. = -9.95, p<0.001) were negatively associated with the incidence of nosocomial MDROs infection.

Conclusions

The multimodal intervention by strengthening the implementation of audit and feedback and the benchmark is feasible and effective in China. The checklist is an effective and practical tool to measure the level of implementation. Education to patients and relatives, hand hygiene, clean of surrounding instruments and bed unit, and sending of specimen inspection timely are especially crucial.

Background

It was estimated that exceeding 700 000 to 10 million deaths were caused by antimicrobial resistance and the cost would accumulate 100 trillion dollars by 2050 all over the world, which was highly correlated to multidrug resistant organisms (MDROs) [1, 2]. MDROs are serious causes of healthcare-associated infections (HAI), which are one of the most common adverse events in healthcare facilities and barriers to quality improvement [3, 4]. Those bacteria have been raised as critical pathogens because they are difficult to treat due to their high percentage of antimicrobial resistance and high mortality [5]. Besides, the spread of MDROs is increasingly recognized and the burden is higher in low and middle-income countries (LMICs), where the prevalence of HAI is twice the average in Europe [6, 7].

MDROs infection prevention and control (IPC) in hospitals is critical and urgent, as antimicrobials available to treat these infections are extremely limited and the development of new antimicrobials is unforeseeable [8]. Researchers found that effective IPC measures can reduce HAI by at least 30% in healthcare facilities, which are the main places for the MDROs spread [9]. Current guidelines issued by WHO, CDC, and other organizations, demonstrated that the most frequently adopted measures include contact precautions, active surveillance cultures, audit and feedback(A&F), patient isolation or cohorting, hand hygiene, and environmental cleaning [3].

Although there were plenty of relevant studies, Tomczyk found that the quality of those studies in MDROs IPC field was very low to low and the level of implementation was unclear [10]. Under that circumstance, Bleasdale recommended that the better implementation of basic IPC elements and more concentration on novel intervention are needed in future studies [11]. However, limited studies explored the implementation level quantitatively of bundle strategies to prevent and control the transmission of pathogens [11, 12]. Most studies ignored the implementation measurement or just measured almost perfect compliance with guidelines during the intervention period [13-15]. Many healthcare workers (even observers themselves) performed the inappropriate use of protective equipment according to guidelines, which was ineffective to prevent the spread of MDROs [11]. Conclusively, there is a need for better implementation and their report [16, 17].

A&F strategy or intervention is extensively applied to improve medical quality practically, which is also applied to ensure the reliable implementation of IPC interventions [3, 18]. A&F was believed to provide the material for behavioral and cultural changes to ensure the reliable implementation of IPC intervention [11]. Allegranzi found that the regular feedback of outcome and process indicators was a crucial lever to improve practices in surgical site infection control even in LMICs [19]. However, several experts on quality improvement found that A&F had the potentially essential but small effect on clinical performances. The reason may be associated with the lack of behavior theory' guidance and implementation heterogeneity [18], and the difficulty to ensure the actionability and the availability of the verified compliance of guidelines [12].

Furthermore, controversy exists about evidence-based approaches and details to prevent MDROs from cross-transmission, especially in LMICs [3]. Therefore, there is an urgent need to improve the implementation of A&F by reliable theories and address the actionability of the implementation process [20], particularly in LMICs like China, which has 1.4 billion people and higher antimicrobial resistance profiles [21]. Besides, benchmarking techniques could help participants in A&F avoid setting unnecessarily low or unrealistically high target levels of performance[22]. Our quasi-experiment study aimed to assess the impact of multimodal intervention which treated A&F and benchmark as key components to reduce the occurrence of MDROs and the implementation effect in three Chinese public hospitals.

Methods

Study setting

This study was designed as before-after and quasi-experiment. The baseline data were collected from 1st March 2018 to 30th September 2018, before the intervention. The intervention was carried out from 1st October 2018 to 30th September 2019. In this study, a multimodal intervention treated A&F and benchmark as key components for MDROs IPC was implemented in three public hospitals in Wuhan, central China. We allocated the hospitals into monthly feedback group (A hospital) and quarterly feedback group (B and C hospital), based on the requirement of those hospitals. The reason for allocation was that the compliance of measures fluctuated unsteadily in one month in B and C hospital due to less MDROs infected patients and limited observed opportunities, which reduced the conviction of feedback for clinical staff [23].

Immediate verbal feedback was given to clinical departments after each audit on the spot in the three hospitals. In the monthly feedback group, monthly written feedbacks were delivered to clinical staff and the IPC committees of departments. The written feedback included the mean level of a hospital as the benchmark and department individual level of 40 A&F implementation indicators [24]. In quarterly feedback group, written feedbacks were delivered quarterly, with the other measures the same as the monthly feedback group. Along with feedbacks, several suggestive approaches and educations aiming at improving the low level of A&F indicators were given to clinical departments and IPC committees of departments. The hospital A had 4 000 beds, providing healthcare services to about 190 000 inpatients and 4.8 million outpatients in 2018. The hospital B and C had 615 beds and 998 beds, respectively. The characteristics of the three participating hospitals were described in Table 1.

A&F multimodal intervention design

In the current study, we adapted the A&F approach to enhance the implementation of multimodal interventions on MDROs IPC. The design process was based on the theoretical model of A&F proposed and recommended by the Healthcare Quality Improvement Partnership and the National Institute for Health and Care Excellence [25, 26].

The dean, leaders of the clinical department, clinical staff, and nosocomial department staff were included in an expert committee to establish the implementation plan. Measures of intervention were chosen from WHO guidelines, China guidelines, and China National health industry standards [3, 9]. The main nine components included hand hygiene, surveillance, contact precaution, patient isolation, environmental cleaning, specimen collection and transport, terminal disinfection and medical waste disposal, standard operating procedure, and appropriate use of antibiotics. A&F implementation indicator pool was developed based on the nine components above and the responsibilities of clinical staffs in MDROs IPC implementation. 40 implementation indicators were confirmed by two rounds of focus discussions based on the indicator pool. (Supplement) Besides, an audit checklist was developed based on those indicators for convenience of use. It is worth mentioning that nurses implemented most measures who were also responsible for reminding, directing, and even supervising environmental cleaners and technicians to implement IPC measures.

Assessment of implementation

The implementation level was measured by the compliance of indicators. A total of 40 training auditors led the A&F multimodal intervention implementation. The auditing was performed twice a week from 8:00-12:00 a.m. based on the audit checklist developed. The paired auditors independently observed IPC behaviors of clinical staff and fulfilled the checklist in one observation. A further mini-interview was also performed to confirm that doctors and nurses did such an operational procedure as usual with patients to lessen the Hawthorne effect. If there was any difference between the two auditors, the consensus was required via discussion with a third person to improve the validity.

Outcomes

Primary outcomes were the monthly incidence of nosocomial MDROs infection of three hospitals per 10 000 patient-days which was detected by clinical culture and acquired more than 48 hours after admission (namely, nosocomial MDROs infection). In our study, we included Carbapenem-resistant Enterobacteriaceae (CRE), Acinetobacter baumannii (CRAB), Pseudomonas aeruginosa (CRPsA), and Methicillin-resistant Staphylococcus aureus (MRSA) into the targeted MDROs, which were considered to need urgent and serious attention of the public [27].

Statistical analyses

Based on the baseline incidence of nosocomial MDROs incidence of 5.55 cases per 10 000 patient-days in the previous study [12], we estimated that both groups would have at least 851 157 patient-day with the assumption of 90% power to show 20% reduction in the incidence of MDROs, with a two-sided type I error of 0.05.

The characteristics and incidence of nosocomial MDROs infected patients were compared by t-test or t'-test and chi-square test [12]. The extent of the intervention changing the incidence of nosocomial MDROs was examined. Poisson segmented linear regression analysis was used to evaluate the effect of the A&F multimodal intervention. As the incidence tended to get a peak in a different season, consequently, we controlled seasonality in our model using harmonic functions [28].

Relationships between the implementation compliance and the incidence were examined using mixed-effect regressions. As data were clustered at the department level, mixed-effect regression analysis was conducted in the monthly feedback group, because only the monthly implementation compliance was available in the monthly feedback group (namely hospital A). There were no missing data in our model. Department-level data were controlled as a random effect. Time elapsed was also considered as the covariate. Descriptive data analysis was performed using IBM SPSS Version 20.0 (IBM, New York, NY, USA). Poisson segmented linear regression and mixed-effect regression analysis were performed using R (Team R Development Core: http://cran.r-project.org/).

The indicators, which were objectively obtained by direct observation or asking patients and relatives, were chosen in our statistical analysis. (Table 2) Other indicators were not included because they were difficult to observe or to ask proper people during the actual implementation. After all, asking nurses or associated medical staff might overestimate the implementation level because of "social desirability" [29]. Nevertheless, they were still treated as implementation indicators for education during the intervention.

Results

A total of 4 465 142 patient-days of 462 837 patients were admitted and hospitalized in the three hospitals. During the intervention period, 1 038 nosocomial and 383 community-associated MDROs infected patients were confirmed.

The incidence of nosocomial MDROs after intervention period showed 19.39%, 20.55%, and 24.03% lower than before in hospitals A, B, and C, respectively. During the preintervention and intervention period, the mortality, age, and gender of MDROs infected patients had no difference before and after intervention in both groups. (Table 1) In the monthly feedback group, the incidence of nosocomial MDROs showed an increasing trend (Coef. =0.05, p=0.07) during the preintervention period. The incidence after intervention showed the negative level (Coef. =-0.06, p=0.82) and trend (Coef. =-0.05, p=0.07). In quarterly feedback group, the level (Coef. =2.42, p=0.008) was positive and the trend (Coef. =-0.32, p<0.001) was negative after the intervention, while the incidence of nosocomial MDROs showed an increasing trend (Coef. =0.19, p=0.03) before intervention in B hospital. The level (Coef. =1.43, p=0.11) was positive and the trend (Coef. =-0.12, p=0.22) was negative but not significant after intervention in hospital C (Figure 1). Durbin-Watson statistic showed the data in three models were sufficiently independent.

All the implementation compliance of practicable indicators was varied and below 100% (Table 2). The lowest three implementation indicators were the use of personal protective equipment (PPE) of doctors (53.05%) and nurses (53.03%) as well as patient isolation of nurses (52.80%). But the hand hygiene compliance of nurses and doctors was approximately 80%. The most observed opportunity was the isolated warning sign of nurses. The least observed opportunity was the use of PPE of doctors.

Hand hygiene compliance of doctors (Coef. =-27.87, p=0.001) and nurses (Coef. =-35.44, p=0.001) were negatively associated with the incidence of nosocomial MDROs (Table 3). Clean of surrounding instruments and bed unit of nurses (Coef. =-4.84, p=0.030) was negatively significant. Education to patients and relatives of nurses (Coef. =-59.51, p=0.031) was negatively related to the incidence of nosocomial MDROs. Sending of specimen inspection timely (Coef. =-9.95, p<0.001) was also negatively associated incidence of nosocomial MDROs. Also, the time elapsed (Coef. =-9.95, p=0.002) from the beginning of the intervention was significantly associated with the decrease of the incidence of nosocomial MDROs. And we found that the use of PPE of nurses was positively correlated (Coef. =13.03, p<0.001). Other implementation indicators showed an insignificant effect on the incidence of nosocomial MDROs.

Table 1
Characteristics of three hospitals and MDROs infected patients in preintervention and intervention period in three hospitals

	Monthly feedback group			Quarterly feedback group					
	Hospital A			Hospital B			Hospital C		
	Preintervention period	Intervention period	P value	Preintervention period	Intervention period	P value	Preintervention period	Intervention period	P value
Incidence of nosocomial MDROs	5.26	4.24	<0.001	3.99	3.17	0.009	2.33	1.77	0.012
Mortality (%) *	13.24	11.45	0.308	14.52	15.00	0.927	23.42	28.72	0.508
Male sex (%)	74.83	69.40	0.364	71.77	72.50	0.959	85.59	75.53	0.552
Age	51.52	51.60	0.981	55.94	53.23	0.412	54.68	57.68	0.189
A&F type	Verbal and monthly written feedback			Verbal and quarterly written feedback			Verbal and quarterly written feedback		

*Mortality= MDROs infected patients dead NO./ MDROs infected patients NO.

Table 2
The implementation compliance of indicators of A&F multimodal intervention

Indicator names	No. Compliance	No. Opportunities	Compliance (%)
Prescription of MDR isolation order of doctors	815	640	78.53
Hand hygiene compliance of doctors	882	717	81.29
Use of PPE of doctors	509	270	53.05
Last operation or warding round of doctors	1,075	878	81.67
Patient isolation of nurses	2,464	1,301	52.80
Isolated warning sign of nurses	2,454	2,384	97.15
Preparation of bedside protective equipment and dedicated instruments of nurses	2,450	1,970	80.41
Restricting access to personnel of nurses	1,616	1,301	80.51
Clean of surrounding instruments and bed unit of nurses	2,269	2,132	93.96
Clean of the ground around bed unit of nurses	2,305	1,843	79.96
Hand hygiene compliance of nurses	2,375	1,912	80.51
Use of PPE of nurses	958	508	53.03
Last operation for patients of nurses	990	930	93.94
Education to patients and relatives of nurses	1,095	1,054	96.26
Sending of specimen inspection timely of nurses	524	336	64.12
Appropriate specimen preservation conditions of nurses	538	430	79.93
Reasonable empirical treatment of antibiotics of doctors	509	478	93.91
Rational targeted therapy of antibacterial drugs of doctors	490	390	79.59

Table 3
. Impacts of implementation compliance of indicators on incidence of nosocomial MDROs

Indicator names	Regression coefficient	Standard error	95%CI	p-value
Time	-1.20	0.39	(-1.96, -0.45)	0.002
Hand hygiene compliance of doctors	-27.87	8.41	(-44.36, -11.39)	0.001
Clean of surrounding instruments and bed unit of nurses	-4.84	2.23	(-9.21, -0.46)	0.030
Hand hygiene compliance of nurses	-35.44	10.79	(-56.59, -14.28)	0.001
Use of PPE of nurses	13.03	2.75	(7.64, 18.42)	<0.001
Education to patients and relatives of nurses	-59.51	27.64	(-27.64, -5.34)	0.031
Sending of specimen inspection timely	-9.95	2.54	(-14.93, -4.98)	<0.001

Discussion

This study designed and conducted a multimodal intervention, mainly based on the A&F and benchmark, to ensure standardized and effective implementation. We not only estimated the effective multimodal intervention impact but also identified whether and what extent did implementation indicators reduce the incidence of nosocomial MDROs. The information obtained may enhance the intervention and implementation of MDROs IPC.

A&F multimodal intervention is associated with the reduction of MDROs infection, which is similar to previous studies conducted in developed countries [30, 31]. A recent systematic review summarized the intervention to control MDROs and found that most studies reported a significant reduction among studies [32]. For example, Li found that the incidence of acquired CRKP colonization/infections showed a rapid decrease at a tertiary-level intensive care unit in China, while they seldomly monitor the compliance of interventions [15].

Some literature reported the relationship between the compliance of separate components (especially hand hygiene) and the incidence of MDROs. For example, some researchers found that wards with hand hygiene compliance higher than 70% were associated with lower incidence rates of MRSA, resistant E. coli, and carbapenem-resistant P. aeruginosa [33]. However, the evidence of how measures in the multimodal intervention (including multiple measures) influenced the incidence of MDROs was limited. In our study, we found that time elapsed was correlated to the decreasing incidence of MDROs, which was consistent with other researchers who estimated that time was associated with the reducing incidence [12, 30]. Interestingly, we found that education to patients and relatives was the most reacted implementation indicators to influence the incidence, which was important to control MDROs spread [34]. It is approved that education to patients and relatives contributed to their participation in IPC, which is essential to keep patients safe and has been promoted by the WHO in the healthcare process [35].

As for the compliance of hand hygiene, both doctors and nurses are associated with decreased incidence. Research conducted in France also found each level (poor, excellent) of improvement of hand hygiene compliance was correlated with a 24% reduction of MRSA acquisition [33]. Moreover, we found that the clean of surrounding instruments and bed unit also influenced the reduction of incidence of MDROs, which was the same as the study in Australia that vancomycin-resistant enterococci infections were reduced after conducting cleaning bundle [36]. As the environment in hospitals especially the surface frequently touched is an important reservoir for the transmission of microorganisms, the environment clean is strongly recommended [37]. Also, we found that the sending of specimen inspection timely was associated with MDROs infection reduction. Although correct specimen collection and transport is important for the appropriate treatment, the current evidence is limited [38].

Different from the previous study, we got a positive coefficient in compliance with the use of PPE in the care process of nurses. Similarly, Enfield found no significant result when implementing contact precautions [14]. As contact precaution was always implemented as part of a bundle IPC intervention, the evidence of isolated effect was currently limited [39]. Although the use of PPE is the primary strategy to prevent transmission, the clinical staff commonly deviated from the correct implementation according to guidelines [11]. Previous studies found that among the observed doffing practices, 90% were incorrect, concerning the sequence, technique, or appropriateness, which increase the possibility of transmission [11, 40]. Meanwhile, it can also be explained that nurses would be more likely to use PPE when caring for patients with serious MDRO infections.

We believe that the high compliance and the key factors of the persistence of multimodal intervention to control MDROs in LMICs were associated closely to the following issues: (1) practicable A&F interventions on improving quality needs an organizational structure and strong leadership in the institute [19, 22]; (2) it is more practicable to transform main components into standardized implementation indicators that can be observed objectively in auditing[35]; (3) quantitative analysis can help to count or measure what is happening now and guide clinical practices [26]; (4) specifying the working scope of doctors and nurses to construct separate implementation indicators, feedback and education can greatly enhance the intervention implementation; (5) benchmark comparison clearly from feedback report could inspire clinical staff to improve the implementation on those indicators below benchmark efficiently according to the control theory [22, 24].

Our study has limitations. No control was selected to verify the effect of the intervention because many hospitals are conservative to get involved due to local policy. The effect of monthly and quarterly feedback may not be comparable, due to the bias caused by the difference in the number of MDROs infected patients in those two groups. Future studies can examine the effect of the frequency of feedback on the outcome.

Conclusion

The multimodal intervention strengthening implementation by A&F and benchmark is associated with the reduction of nosocomial MDROs incidence. Several indicators of core components during implementation period including hand hygiene, environmental cleaning, use of PPE of nurses, education to patients and relatives, and sending of specimen inspection timely are associated with nosocomial MDROs incidence.

List Of Abbreviations

MDROs: multidrug resistant organisms; HAI: healthcare-associated infections; LMICs: low and middle-income countries; IPC: infection prevention and control; A&F: audit and feedback; CRE: Carbapenem-resistant Enterobacteriaceae; CRAB: Acinetobacter baumannii; CRPsA: Pseudomonas aeruginosa; MRSA: Methicillin-resistant Staphylococcus aureus; PPE: personal protective equipment

Declarations

Ethics approval and consent to participate

Our study was approved by the Ethics Committee of Tongji Medical College, Huazhong University of Science and Technology (IORG: IORG0003571).

Consent for publication

Not applicable.

Availability of data and materials

The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request.

Competing interests

None.

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Authors' contributions

QZ and XPZ developed the design and drafted the manuscript. XQL collected data, along with the study team. QZ analyzed the data and XPZ revised the manuscript. All authors contributed to the design of the study and approved the final version of the article.

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References

1. Jasovský D, Littmann J, Zorzet A, Cars O. Antimicrobial resistance-a threat to the world's sustainable development. *Ups J Med Sci* 2016; 121:159-164.
2. O'NEILL J. Tracking Drug-Resistant Infections Globally: Final Report and Recommendations. *Review on antimicrob resis* 2016.
3. WHO: Guidelines for the prevention and control of carbapenem-resistant Enterobacteriaceae, Acinetobacter baumannii and Pseudomonas aeruginosa in health care facilities. In.; 2016.
4. Burrell SJ, Bull AL, Worth LJ. Measuring Healthcare-Associated Infection Outcomes: Enhanced Surveillance to Include Process Adherence for Quality Improvement. *Stud Health Technol Inform* 2019; 264:1833-1834.
5. Weiner LM, Webb AK, Limbago B. Antimicrobial-Resistant Pathogens Associated With Healthcare-Associated Infections: Summary of Data Reported to the National Healthcare Safety Network at the Centers for Disease Control and Prevention, 2011-2014. *Infect Control Hosp Epidemiol* 2016; 37:1288-1301.
6. Laxminarayan R, Duse A, Wattal C, Zaidi AKM, Wertheim HFL, Sumpradit N, Vlieghe E, Hara GL, Gould IM, Goossens H *et al*. Antibiotic resistance—the need for global solutions. *The Lancet Infectious Diseases* 2013; 13:1057-1098.
7. Allegranzi B, Nejad SB, Combescure C, Graafmans W, Attar H, Donaldson L, Pittet D. Burden of endemic health-care-associated infection in developing countries: systematic review and meta-analysis. *The Lancet* 2011; 377:228-241.
8. Renwick MJ , Brogan DM , Mossialos E. A systematic review and critical assessment of incentive strategies for discovery and development of novel antibiotics. *J Antibiot* 2015.
9. Seto WH TD, Yung RW,. Effectiveness of precautions against droplets and contact in prevention of nosocomial transmission of severe acute respiratory syndrome (SARS). *Lancet* 2003; 361:1519-1520.
10. Tomczyk S, Zanichelli V, Grayson ML. Control of Carbapenem-resistant Enterobacteriaceae, Acinetobacter baumannii, and Pseudomonas aeruginosa in Healthcare Facilities: A Systematic Review and Reanalysis of Quasi-experimental Studies. *Clin Infect Dis* 2019; 68:873–884.
11. Bleasdale SC. Do We Need Another Study to Control Carbapenemresistant Organisms, or Do We Just Need to Get Better at the Basics? *Clin Infect Dis* 2019; 68:885-886.
12. Schwaber MJ , Lev B , Israeli A. Containment of a Country-wide Outbreak of Carbapenem-Resistant Klebsiella pneumoniae in Israeli Hospitals via a Nationally Implemented Intervention. *Clin Infect Dis* 2011; 52:848-855.
13. Schwaber M J , Lev B , A I. Containment of a Country-wide Outbreak of Carbapenem-Resistant Klebsiella pneumoniae in Israeli Hospitals via a Nationally Implemented Intervention. *Clinical Infectious Diseases* 2011; 52:848-855.
14. Enfield KB , Huq NN , Gosseling MF. Control of Simultaneous Outbreaks of Carbapenemase-Producing Enterobacteriaceae and Extensively Drug-Resistant\r, Acinetobacter baumannii\r, Infection in an Intensive Care Unit Using Interventions Promoted in the Centers for Disease Control and Prevention 2012 Carbapenemase-Resistant Enterobacteriaceae Toolkit. *Infect Control Hosp Epidemiol* 2014; 35:810-817.
15. Li M , Wang X , Wang J. Infection-prevention and control interventions to reduce colonisation and infection of intensive care unit-acquired carbapenem-resistant Klebsiella pneumoniae: a 4-year quasi-experimental before-and-after study. *Antimicrob Resist Infect Control* 2019; 8.
16. Trick WE , Vernon MO , Welbel SF. Multicenter Intervention Program to Increase Adherence to Hand Hygiene Recommendations and Glove Use and to Reduce the Incidence of Antimicrobial Resistance. *Infect Control Hosp Epidemiol* 2007; 28:42-49.
17. Mulvey D, Mayer N, Visnovsky L. Frequent and unexpected deviations from personal protective equipment guidelines increase contamination risks. *Am J Infect Control* 2019; 47:1146-1147.
18. Ivers N, Jamtvedt G, Flottorp S. Audit and feedback: effects on professional practice and healthcare outcomes. *Cochrane Database Syst Rev* 2012; 6:CD000259.
19. Allegranzi B , Aiken AM , Zeynep Kubilay N. A multimodal infection control and patient safety intervention to reduce surgical site infections in Africa: a multicentre, before–after, cohort study. *Lancet Infect Dis* 2018; 18:507-515.
20. Gude WT, van Engen-Verheul MM, van der Veer SN. Effect of a web-based audit and feedback intervention with outreach visits on the clinical performance of multidisciplinary teams: a cluster-randomized trial in cardiac rehabilitation. *Implement Sci* 2015; 11:160.
21. Hu F, Zhu D, Wang F. Current Status and Trends of Antibacterial Resistance in China. *Clin Infect Dis* 2018; 67:S128-S134.
22. Gude WT , Brown B , van der Veer SN. Clinical performance comparators in audit and feedback: A review of theory and evidence. *Implement Sci* 2019; 14:39.
23. Cooke LJ, Duncan D, Rivera L, Dowling SK, Symonds C, Armson H. How do physicians behave when they participate in audit and feedback activities in a group with their peers? *Implement Sci* 2018; 13.
24. Gude WT, van Engen-Verheul MM, van der Veer SN. How does audit and feedback influence intentions of health professionals to improve practice? A laboratory experiment and field study in cardiac rehabilitation. *BMJ Qual Saf* 2016; 26:bmjqs-2015-004795.

25. National Institute for Health and Care Excellence: Principles for Best Practice in Clinical Audit.https://www.nice.org.uk/media/default/About/what-we-do/Into-practice/principles-for-best-practice-in-clinical-audit.pdf; Accessed 29 Jan 2020.
26. Healthcare Quality Improvement Partnership: Guide to Using Quality Improvement Tools to Drive Clinical Audits. https://www.hqip.org.uk/resource/hqip-guide-to-using-quality-improvement-tools-to-drive-clinical-audit/#.XYYKfaYzY2w Accessed 29 Jan 2020.
27. Centers for Disease Control and Prevention: Antibiotic resistance threats in the United States.http://www.cdc.gov/drugresistance/threat-report-2013/pdf/ar-threats-2013-508.pdf.; Accessed 29 Jan 2020.
28. Bernal JL, Cummins S, Gasparrini A. Interrupted time series regression for the evaluation of public health interventions: a tutorial. *Int J Epidemiol* 2017; 46:348-355.
29. Edwards B. The Social Desirability Variable in Personality Assessment and Research. *Academic Medicine* 1982; 33.
30. Gagliotti C , Cappelli V , Carretto E. Control of carbapenemase-producing Klebsiella pneumoniae: a region-wide intervention. *European communicable disease bulletin* 2014; 19:pii=20943.
31. Hayden MK , Lin MY , Lolans K. Prevention of Colonization and Infection by Klebsiella pneumoniae Carbapenemase-Producing Enterobacteriaceae in Long-term Acute-Care Hospitals. *Clinical Infectious Diseases* 2015; 60:1153-1161.
32. Sara Tomczyk, Veronica Zanichelli, Grayson ML. Control of Carbapenem-resistant Enterobacteriaceae, Acinetobacter baumannii, and Pseudomonas aeruginosa in

Healthcare Facilities: A Systematic Review and Reanalysis of Quasi-experimental Studies. *Clinical Infectious Diseases* 2019; 68:873–884.

33. Girou E , Legrand P , Soing-Altrach S. Association Between Hand Hygiene Compliance and Methicillin-Resistant Staphylococcus aureus Prevalence in a French Rehabilitation Hospital. *Infect Control Hosp Epidemiol* 2006; 27:1128-1130.
34. Gammon J , Hunt J , Williams S. Infection prevention control and organisational patient safety culture within the context of isolation: Study protocol. *BMC Health Serv Res* 2019; 19.
35. WHO.Patients for Patient Safety,https://www.who.int/patientsafety/patients_for_patient/en/. Accessed 29 Jan 2020.
36. Mitchell BG, Hall L, White N, Barnett AG. An environmental cleaning bundle and health-care-associated infections in hospitals (REACH): a multicentre, randomised trial. *Lancet Infect Dis* 2019; 19:410-418.
37. Kramer A, Schwebke I, Kampf G. How long do nosocomial pathogens persist on inanimate surfaces? A systemic review. *BMC Infect Dis* 2006; 6.
38. Hu BJ. Chinese carbapenem-resistant Gram-negative bacilli (CRO) infection prevention and control technology guidelines. *Chinese Journal of Nosocomiology* 2019; 29:2075-2080.
39. Tschudin-Sutter S , Lucet JC , Mutters NT. Contact precautions for preventing nosocomial transmission of ESBL-producing Escherichia coli – a point/counterpoint review. *Clin Infect Dis* 2017; 65:342–347.
40. Phan LT, Maita D, Mortiz DC. Personal protective equipment doffing practices of healthcare workers. *J Occup Environ Hyg* 2019; 16:575-581.

Figures

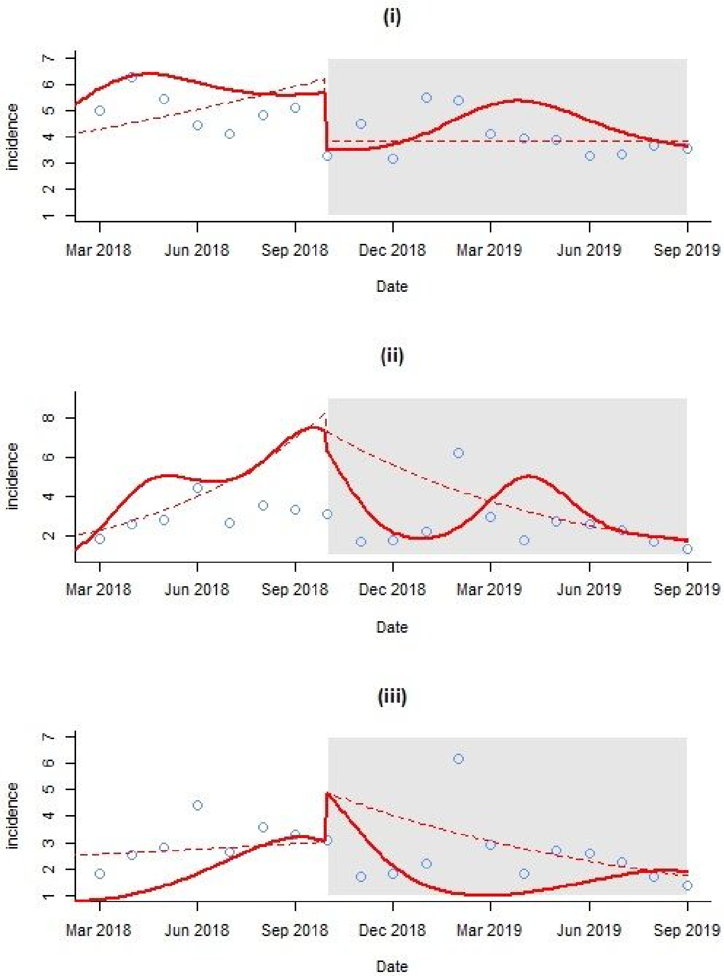

Figure 1

Effect of the intervention on incidence (i): hospital A (ii): hospital B (iii): hospital C

Supplementary Files

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- supplement.docx