Antimicrobial Stewardship Interventions: Narrative Review

Nehad J. Ahmed¹,²*, Abdul Haseeb³, Azmi Ahmed Hassali⁴ and Amer H. Khan²

¹Department of Clinical Pharmacy, Pharmacy College, Prince Sattam Bin Abdulaziz University, Saudi Arabia.
²Department of Clinical Pharmacy, Pharmacy College, Universiti Sains Malaysia, Malaysia.
³Clinical Pharmacy Department, College of Pharmacy, Umm AlQura University, Saudi Arabia.
⁴Discipline of Social Pharmacy, School of Pharmaceutical Sciences, Universiti Sains Malaysia, Malaysia.

Authors’ contributions:

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/JPRI/2021/v33i23B31422

Editor(s): (1) Dr. Ana Cláudia Coelho, University of Trás-os-Montes and Alto Douro, Portugal.

Reviewers: (1) Patrizia Farruggia, University of Bologna, Italy.
(2) Daniela Almeida Rodrigues, Polytechnic Institute of Guarda (UDI/IPG), Portugal.

Complete Peer review History: http://www.sdiarticle4.com/review-history/67230

Received 02 February 2021
Accepted 07 April 2021
Published 16 April 2021

ABSTRACT

Antimicrobial resistance is a serious health concern with significant economic and clinical sequelae. Antimicrobial stewardship programs are increasingly being promoted and mandated in order to rationalize and reduce the use of antimicrobials in healthcare institutions and as a result decrease antimicrobial resistance. Several interventions could be used to improve antibiotic use that includes broad, pharmacy driven and infection and syndrome specific interventions. Each hospital should prioritize interventions based on its needs as well as based on the availability of resources and content expertise.

Keywords: Antibiotics use; antimicrobial use; antimicrobial resistance; antimicrobial stewardship programs; interventions.

*Corresponding author: E-mail: pharmdnehadjaser@yahoo.com;
1. INTRODUCTION

Antimicrobial resistance (AMR) is a serious health concern with significant economic and clinical sequelae. The incidence of it is rapidly increasing around the world, and infections caused by organisms that are resistant to several antibiotics are associated with higher incidences of mortality, morbidity, and prolonged hospital admission [1]. The main driver of the emergence of antimicrobial resistance is the selective pressure of antimicrobial usage on microorganisms; therefore, considerable focus has been placed on ensuring the wise use of antimicrobials [2]. Not only does this have implications for the patient who is infected with multidrug resistant organisms, but also for the spread of these organisms in the community and in healthcare facilities at large [2]. Consequently, antimicrobial stewardship programs are increasingly being promoted and mandated in order to rationalize and reduce the use of antimicrobials in healthcare institutions [3].

Antimicrobial stewardship (AMS) is a systematic approach to ensure that the antimicrobial use is appropriate, it aims to optimize the treatment of infections, minimize the adverse effects associated with antibiotic use and reduce antimicrobial resistance, toxicity and costs [4,5]. Antimicrobial stewardship can have a positive impact the different facilities largely [6]. There are several elements of antimicrobial stewardship programs, including post-prescription review, pre-prescription authorization, education of prescribers, regular ward rounds for review of antimicrobial use, and regular audits with feedback [3]. Antimicrobial pharmacists remain leaders for implementing the interventions of antimicrobial stewardship programs across both primary and secondary healthcare institutions [7].

Interventions to decrease the unsuitable antimicrobial prescribing can reduce antimicrobial resistance or healthcare-acquired infections, and interventions to increase effective prescribing are essential in improving patient safety clinical outcomes [8]. This review aims to describe the interventions of antimicrobial stewardship programs.

2. METHODS

This narrative review was included searching Pubmed databases for the key terms (antimicrobial stewardship interventions). The searching process was conducted on 02-Dec-2020 and included the published articles in the last 10 years. So, the studies that were published before 10 years and review articles were excluded from the study.

The searching results were limited to the articles that were published in the 10 years and also the searching was limited by choosing the articles that contain the key terms “antimicrobial stewardship interventions” in the title of the articles that were written in English. We also add other studies from the references of the included articles.

3. RESULTS AND DISCUSSION

The searching process resulted in a total of 34 articles and review articles. After excluding review articles; 26 studies were identified and included in our review. Other studies were added from the references of the included articles after ensuring that they were related to the study topic and that they were published in the last 10 years. Table 1 showed the included publications that were published before 2017 and Table 2 showed the included publications that were published after 2016.

3.1 Antimicrobial Stewardship Interventions

The Infectious Diseases Society of America recommends 2 core strategies for antimicrobial stewardship— antimicrobial restriction/preauthorization and postprescription audit and review (PPR) with intervention and feedback [9,10]. Barlam et al. [10] and Davey et al. [8] stated that the primary goal of hospital antimicrobial stewardship programs is to improve patient care. Evidence-based strategies include individualized active interventions to positively impact decisions about antimicrobials and review of patient-specific clinical data and prescriber-targeted. Chavada et al. [11] stated that in addition to optimizing the duration of treatment, other practical interventions may also help to improve prescribing in this particular area such as prospective audit and feedback specifically for discharge antimicrobials, prescriber education, and the introduction of electronic prescribing and flagging. Pettit et al. [12] conducted a study about the use of Epic antimicrobial stewardship module which is Clinical Decision Support Tool and found that this module allowed us to significantly increase the number of antimicrobial reviews and interventions while maintaining a sustained impact on antimicrobial utilization.
Table 1. The included publications that were published before 2017

| Publications                                      | Year |
|--------------------------------------------------|------|
| Dellit et al.                                    | 2007 |
| Scottish Intercollegiate Guidelines Network      | 2008 |
| De Kraker ME et al.                              | 2011 |
| Holtzman et al.                                  | 2011 |
| SNLG                                             | 2011 |
| Shrestha et al.                                  | 2012 |
| Patel et al.                                     | 2012 |
| Vlek et al.                                      | 2012 |
| Abdel-Aziz et al.                                | 2013 |
| Huang et al.                                     | 2013 |
| Dellinger et al.                                 | 2013 |
| Davey et al.                                     | 2013 |
| The Centers for Disease Control and Prevention   | 2014 |
| Hamilton and Fishman                             | 2014 |
| Reed et al.                                      | 2014 |
| Gauthier et al.                                  | 2014 |
| Cairns et al.                                    | 2015 |
| Ashiru-Oredope et al.                            | 2016 |
| Barlam et al.                                    | 2016 |
| Caplinger et al.                                 | 2016 |
| Morton et al.                                    | 2016 |
| Ashiru-Oredope et al.                            | 2016 |
| Cao et al.                                       | 2016 |
| Pardo et al.                                     | 2016 |
| Hersh et al.                                     | 2016 |
| Turnidge et al.                                  | 2016 |

Table 2. The included publications that were published after 2016

| Publications                                      | Year |
|--------------------------------------------------|------|
| Sartelli et al.                                  | 2017 |
| Badia et al.                                     | 2017 |
| Schmitt et al.                                   | 2017 |
| Goff et al.                                      | 2017 |
| Berrios-Torres et al.                            | 2017 |
| Dilworth et al.                                  | 2017 |
| Dumkow et al.                                    | 2017 |
| Beganovic et al.                                 | 2017 |
| Jones et al.                                     | 2017 |
| Avdic et al.                                     | 2017 |
| Bates et al.                                     | 2017 |
| Chavada et al.                                   | 2018 |
| Ruscelli et al.                                  | 2018 |
| Gillespie et al.                                 | 2018 |
| Patton et al.                                    | 2018 |
| Flett et al.                                     | 2018 |
| Pettit et al.                                    | 2018 |
| Borek et al.                                     | 2019 |
| Tang et al.                                      | 2019 |
| Nguyen et al.                                    | 2019 |
| Niwa et al.                                      | 2019 |
| Hecker et al.                                    | 2019 |
| Anderson et al.                                  | 2019 |
| Stevens et al.                                   | 2020 |
Davey et al. [8] stated that interventions to reduce inappropriate antimicrobial prescribing can reduce healthcare-acquired infections or antimicrobial resistance. Moreover, interventions to increase effective prescribing are important in improving patient safety clinical outcomes. Previous studies suggested several strategies including a pharmacy-based triage algorithm for pneumonia, the implementation of an antimicrobial stewardship model following patients discharged on antimicrobial therapy with pending culture results and subsequent modification of antimicrobial therapy, a checklist framework for pediatric patients, and a mandatory Infectious Disease Consultation of intended community-based parenteral antimicrobial therapy [13–15].

Morton et al. [16] stated that antimicrobial stewardship interventions were organized into 11 categories including drug dose or duration optimization, antimicrobial discontinuation, vancomycin dosing, de-escalation of therapy, intravenous to oral switch, ordering of a pertinent Laboratory test for monitoring purposes, broadening of antimicrobial spectrum, therapeutic drug monitoring, Infectious Disease consultation, addressing a drug–drug interaction between an antimicrobial and another medication, or change in antimicrobial regimen due to reported allergic reaction. They also found that verbal communication is now the primary method of providing antimicrobial stewardship interventions at their facility and that stewardship practices may be improved by limiting the use of potentially less effective communication methods; this will lead to improving patient outcomes, potentially reducing inappropriate antimicrobial use, and decreasing resistance rates [17]. Stevens et al. [17] compared the acceptance rates of interventions communicated with a temporary note left in the electronic medical record versus those communicated telephonically and found that telephonic communication produced superior overall acceptance rates.

Borek et al. reported that the most promising and feasible antimicrobial stewardship interventions included multidisciplinary peer learning, quality improvement, auditing individual-level prescribing, appointing AMS leads, improving inductions for new prescribers, developing tools for prescribing audits, providing online AMS training to all patient-facing staff, increasing staff time available for AMS work with standardizing AMS-related roles, and ensuring consistent local approaches to antibiotic prescribing [18]. They also stated that these interventions could be developed as stand-alone interventions or incorporated into existing national interventions to optimize antibiotic prescribing in primary care in England [18]. Centers for Disease Control and Prevention said that stewardship interventions are listed in three categories below: broad, pharmacy-driven; and infection and syndrome specific [19].

### 3.1.1 Broad interventions

Broad interventions include several interventions such as prior authorization and prospective audit and feedback [19]. Some authors have reported some suggested actions from the European Centre for Disease Prevention and Control to increase compliance to the recommendations that include audit and feedback, shifting the responsibility of surgical antibiotic prophylaxis administration to the anesthesiologist, education and training, implementation of a multidisciplinary management team and implementation of standardized order form [11]. Tang et al. [20], stated that the implementation of multidisciplinary, frontline provider-driven approaches to antimicrobial stewardship in addition to educational bundle may lead to reduced antibiotic use and length of hospital stay. Dellinger et al. [21] reported that education antibiotic stewardship programs should provide regular updates on antibiotic resistance, antibiotic prescribing, and infectious disease treatment that address both local and national. Patel et al. [22] and Gauthier et al. [23] stated that there are a variety of web-based educational resources such as CDC TRAIN Learning Network available that can help facilities develop education content.
Nguyen et al. reported that the implemented interventions include prospective audit with feedback and intervention, provider education using educational sessions and pocket cards, and institutional guideline update [24]. They also support the call for antimicrobial stewardship programs to improve antibiotic use upon discharge and to reduce overall antimicrobial exposure [25]. Ashiru-Oredope et al. recommended numerous interventions which are the provision of an antimicrobial stewardship committee, the implementation of audits, a written education and training strategy, and a written dedicated antimicrobial policy [24].

Anderson et al. reported that post-prescription audit and review was a feasible and effective strategy for antimicrobial stewardship in settings with limited resources and expertise and that it led to more interventions, particularly de-escalation, which likely influenced overall antimicrobial use [26]. They also stated that these interventions led to more interactions between prescribers and pharmacists, providing additional opportunities to optimize antimicrobial therapy [26]. Atkins et al. reported that the majority of interventions in their study focused on education and training, which target knowledge and skills through the provision of instructions on how to perform a behavior and information about health consequences. Atkins et al study highlights the need to review existing interventions to ensure they are optimized to influence AMR-related behaviors [27].

3.1.2 Pharmacy-driven interventions

These interventions include automatic changes from intravenous to oral antibiotic therapy, dose adjustments, dose optimization, automatic alerts in situations where therapy might be unnecessarily duplicative, time-sensitive automatic stop orders for specified antibiotic prescriptions, especially antibiotics administered for surgical prophylaxis and detection and prevention of antibiotic-related drug-drug interactions [19]. Previous studies with pharmacist-led initiatives have shown an improvement in the overall appropriateness of antimicrobial therapy [28,29]. Chavada et al. envisage the introduction of several strategies such as training and upskilling of clinical pharmacists who already perform discharge medication reconciliation for antimicrobial therapy prescribed on hospital discharge [11].

Cao et al. conducted an institutional review of antimicrobial stewardship interventions and reported that the most frequent types of interventions were pharmacy-driven interventions and were related to inappropriate dosing (39.0%), antimicrobial selection (20.5%) and drug allergy (13.0%). They also stated that serious adverse drug events were potentially avoided in about 20.7% of all interventions and that the cumulative potential cost avoidance was more than US$6.5 million [30].

3.1.3 Infection and syndrome specific interventions

These interventions are implemented for specific infection and syndrome, such as interventions for community-acquired pneumonia, urinary tract infections, skin and soft tissue infections, surgical antibiotic prophylaxis, empiric coverage of methicillin-resistant staphylococcus aureus infections, clostridium difficile infections, and treatment of culture proven invasive infections.

One of the most common Infections and syndrome specific interventions are the interventions that are implemented to improve surgical antibiotic prophylaxis. Badia et al. reported that the appropriate usage of surgical antibiotic prophylaxis significantly decreases the risk of surgical site infections [31], while the inappropriate usage increases surgical site infections, multidrug-resistant strains, and hospital costs [32-34]. For this reason, international and national guidelines have been developed to guide clinicians in the optimal use of surgical antibiotic prophylaxis [35-37]. Tiri et al. stated that many guidelines about surgical antibiotic prophylaxis have been published, but the overall compliance remains poor [38]. They used educational audit intervention and found that this intervention improves appropriateness on surgical antibiotic prophylaxis [38].

Pardo et al. reported that the Blood Culture Identification, coupled with antimicrobial stewardship intervention, was a cost-effective tool to improve patient care [39]. Niwa et al. reported that Matrix-assisted laser desorption ionization-time of flight mass spectrometry combined with antimicrobial stewardship intervention facilitated early optimization of antimicrobial therapy with a remarkable concomitant reduction in adverse events and clinical failure in patients with bloodstream infections [40]. Bates et al. found that C-reactive protein point-of-care testing was effective in safely decreasing antibiotic use in patients with an acute exacerbation of chronic obstructive
bacterial infection [42]. Hecker et al. conducted specific interventions on the use of and resistance to fluoroquinolones and found that Antimicrobial stewardship interventions focused on specific syndromes may be effective in decreasing the use of fluoroquinolone use. They also found that the reduction in fluoroquinolone use resulted in a decrease in the resistance of *P. aeruginosa* to fluoroquinolone [43].

Several studies also reported that rapid diagnostic tests such as fluorescence in situ hybridization using peptide nucleic acid probes, procalcitonin and matrix-assisted laser desorption/ionization time of flight mass spectrometric analysis have been effectively incorporated by some stewardship programs and may become essential additions to stewardship programs [44-47]. Reed et al. conducted a study regarding the use of antimicrobial stewardship interventions in the management of candidemia and found that the pharmacist interventions in antimicrobial stewardship programs standardized and improved the quality of care of candidemia patients [48]. Moreover, Jones et al. stated that antimicrobial stewardship programs developed management pathways to monitor the use of potential COVID-19 therapies to confirm that the treatment is appropriate and to lessen toxicities and adverse events [49]. They also stated that their interventions served as a model for leveraging the collaborative relationship between antimicrobial stewardship programs and pharmacists during the pandemic of COVID-19 [49].

Avdic et al. found that the use of a real-time antimicrobial stewardship intervention implemented with the introduction of the Verigene Gram-Positive Blood Culture assay for patients with bacteraemia due to gram-positive cocci led to improvements in antibiotic therapy [50]. Patton et al. stated that despite the decreases in high-risk antimicrobials prescribing and decreased in clostridium difficile infection, establishing the real-world impact of antimicrobial stewardship interventions remains challenging [51]. Staub et al. conducted a study about the effect of antimicrobial stewardship interventions in improving outpatient antibiotic prescriptions and said that the best strategy to implement effective antimicrobial stewardship interventions is targeting high prescribers [52]. Flett et al. found that antimicrobial stewardship interventions and spaced education decreased the redundant anaerobic therapy [53]. Beganovic et al. confirmed that rapid identification with matrix-assisted laser desorption ionization–time of flight mass spectrometry combined with real-time antimicrobial stewardship intervention is more impactful than matrix-assisted laser desorption ionization–time of flight mass spectrometry alone [54]. Shallcross et al. prepared a protocol for preserving antibiotics through a safe stewardship research program and reported that this protocol aimed to develop evidence-based antibiotic stewardship interventions targeted to specific healthcare settings [55]. Dilworth et al. reported that the use of frontline pharmacists to improve compliance and quality of care components for Staphylococcus aureus bacteremia is impressive and meets the workflow needs of advanced antimicrobial stewardship programs [56].

4. CONCLUSION

Several interventions could be used to improve antibiotic use that can be divided into three categories: broad, pharmacy driven and infection and syndrome specific interventions. Each hospital should determine the appropriate interventions that it will implement and should prioritize interventions based on its needs as well as based on the availability of resources and content expertise. Centers for Disease Control and Prevention advised hospitals to avoid implementing too many policies and interventions at the same time [19].

CONSENT

It is not applicable.

ETHICAL APPROVAL

It is not applicable.

ACKNOWLEDGEMENT

This Publication was supported by the Deanship of Scientific Research at Prince Sattam bin Abdulaziz University.

COMPETING INTERESTS

Authors have declared that no competing interests exist.
REFERENCES

1. De Kraker ME, Davey PG, Grundmann H, BURDEN Study Group. Mortality and hospital stay associated with resistant *Staphylococcus aureus* and *Escherichia coli* bacteremia: Estimating the burden of antibiotic resistance in Europe. PLOS Med. 2011;8:e1001104.

2. Turnidge JD, Thursky K, Chen CS, McNeil VR, Wilkinson IJ. Antimicrobial use in Australian hospitals: How much and how appropriate?. Med J Aust. 2016;205:s16–20.

3. Cairns KA, Roberts JA, Cotta MO, Cheng AC. Antimicrobial stewardship in Australian hospitals and other settings. Infect Dis Ther. 2015;4:27–38.

4. Sartelli M, Labricciosa FM, Barbadoro P, Pagani L, Ansaloni L, Brink AJ, et al. The global alliance for infections in surgery: Defining a model for antimicrobial stewardship-results from an international cross-sectional survey. World J Emerg Surg. 2017;12:34.

5. Goff DA, Kullar R, Goldstein EJ, Gilchrist M, Nathwani D, Cheng AC, et al. A global call from five countries to collaborate in antibiotic stewardship: United we succeed, divided we might fail. Lancet Infect Dis. 2017;17:e56–e63.

6. Hamilton KW, Fishman NO. Antimicrobial stewardship interventions: Thinking inside and outside the box. Infect Dis Clin. 2014;28:301-313.

7. Ashiru-Oredope D, Budd EL, Bhattacharya A, Din N, McNulty CAM, Micallef C, et al. Implementation of antimicrobial stewardship interventions recommended by national toolkits in primary and secondary healthcare sectors in England: TARGET and Start Smart Then Focus. J Antimicrob Chemother. 2016;71:1408-1414.

8. Davey P, Brown E, Charani E, Fenelon L, Gould IM, Holmes A, et al. Interventions to improve antibiotic prescribing practices for hospital inpatients. Cochrane Database of Systematic Reviews. 2013;4:CD003543.

9. Dellit TH, Owens RC, McGowan JE, Gerding DN, Weinstein RA, Burke JP, et al. Infectious Diseases Society of America and the Society for Healthcare Epidemiology of America guidelines for developing an institutional program to enhance antimicrobial stewardship. Clin Infect Dis. 2007;44:159-177.

10. Barlam TF, Cosgrove SE, Abbo LM, MacDougall C, Schuetz AN, Septimus EJ, et al. Implementing an antibiotic stewardship program: Guidelines by the Infectious Diseases Society of America and the Society for Healthcare Epidemiology of America. Clin Infect Dis. 2016;62:e51-e77.

11. Chavada R, Davey J, O’Connor L, Tong D. Careful goodbye at the door: Is there role for antimicrobial stewardship interventions for antimicrobial therapy prescribed on hospital discharge? BMC Infect Dis. 2018;18:1-6.

12. Pettit NN, Han Z, Choksi AR, Charnotskis A, Beavis KG, Tesic V, et al. Improved rates of antimicrobial stewardship interventions following implementation of the Epic antimicrobial stewardship module. Infect Control Hosp Epidemiol. 2018;39:980-982.

13. Caplinger C, Crane K, Wilkin M, Bohan J, Remington R, Madaras-Kelly K. Evaluation of a protocol to optimize duration of pneumonia therapy at hospital discharge. Am J Hosp Pharm. 2016;73:2043–54.

14. Shrestha NK, Bhaskaran A, Scaleram NM, Schmitt SK, Rehm SJ, Gordon SM. Antimicrobial stewardship at transition of care from hospital to community. Infect Control Hosp Epidemiol. 2012;33:401–4.

15. Hersh AL, Newland JG, Gerber JS. Pediatric antimicrobial discharge stewardship: An unmet need. JAMA Pediatr. 2016;170:191–2.

16. Morton JB, Curzake DJ, Morrill HJ, Parente DM, Gaitanis MM, LaPlante KL. Verbal communication with providers improves acceptance of antimicrobial stewardship interventions. Infect Control Hosp Epidemiol. 2016;37:740-2.

17. Stevens RW, Fjeld HD, Cutchins C, Westley BP. Method to the madness: Impact of method of contact on intervention acceptance rates for antimicrobial stewardship interventions. Infect Control Hosp Epidemiol. 2020;41:959-961.

18. Borek AJ, Wanat M, Sallis A, Ashiru-Oredope D, Atkins L, Beech E, et al. How can national antimicrobial stewardship interventions in primary care be improved? A Stakeholder Consultation. Antibiotics (Basel, Switzerland). 2019;8:207.

19. Centers for Disease Control and Prevention. The core elements of hospital antibiotic stewardship programs.
28. Dumkow LE, Beuschel TS, Brandt KL. Expanding antimicrobial stewardship to urgent care centers through a pharmacist-led culture follow-up program. Infect Dis Ther. 2017;6:453–9.

29. Jones JM, Leedahl ND, Losing A, Carson PJ, Leedahl DD. Pilot study for antimicrobial stewardship post-discharge. J Pharm Pract. 2017;31(7):897190017699775.

30. Cao H, Phe K, Laine GA, Russo HR, Putney KS, Tam VH. An institutional review of antimicrobial stewardship interventions. J Glob Antimicrob Resist. 2016;6:75-77.

31. Badia JM, Casey AL, Petrosillo N, Hudson PM, Mitchell SA, Crosby C. Impact of surgical site infection on healthcare costs and patient outcomes: A systematic review in six European countries. J Hosp Infect. 2017:96:1–15.

32. Schmitt C, Lacerda RA, Turrini RNT, Padoveze MC. Improving compliance with surgical antibiotic prophylaxis guidelines: A multicenter evaluation. Am J Infect Control. 2017;45:1111–1115.

33. Abdel-Aziz A, El-Menyar A, Al-Thani H, Zarour A, Parchani A, Asim M, et al. Adherence of surgeons to antimicrobial prophylaxis guidelines in a tertiary general hospital in a rapidly developing country. Adv Pharmacol Sci. 2013;2013:1–6.

34. Ruscelli P, Renzi C, Polistena A, Sanguinetti A, Avenia N, Popivanov G, et al. Clinical signs of retroperitoneal abscess from colonic perforation. Medicine. 2018;97:e13176.

35. SNLG17. Antibiotico profilassi perioratoria nell’adulto LINEA GUIDA. Accessed 20 March 2021 Available:https://www.anmdo.org/wp-content/uploads/2016/10/Linee-guida-Antibiotico-profilassi-perioratoria-nelladulto.pdf

36. Berrios-Torres SI, Umscheid CA, Bratzler DW, Leas B, Stone EC, Kelz RR, et al. Centers for Disease Control and Prevention Guideline for the Prevention of Surgical Site Infection, 2017. JAMA Surg. 2017;152(8):784-791.

37. Scottish Intercollegiate Guidelines Network. Antibiotic prophylaxis in surgery. Accessed 20 March 2021 Available:http://www.sign.ac.uk/pdf/sign104.pdf

38. Tiri B, Bruzzzone P, Priante G, Sensi E, Costantini M, Vennelli C, et al. Impact of antimicrobial stewardship interventions on appropriateness of surgical antibiotic use/healthcare/pdfs/core-elements.pdf

26. Anderson DJ, Watson S, Moehring RW, Komarow L, Finnemeyer M, Arias RM, et al. Feasibility of core antimicrobial stewardship interventions in community hospitals. JAMA Netw Open. 2019;2:e199369.

27. Atkins L, Chadborn T, Bondaronek P, Ashiru-Oredope D, Beech E, Herd N, et al. Content and mechanism of action of national antimicrobial stewardship interventions on management of respiratory tract infections in primary and community care. Antibiotics (Basel). 2020;9:512.

20. Tang SJ, Gupta R, Lee JI, Majid AM, Patel P, Efird L, et al. Impact of hospitalist-led interdisciplinary antimicrobial stewardship interventions at an Academic Medical Center. Jt Comm J Qual Patient Saf. 2019;45:207-216.

21. Dellinger RP, Levy MM, Rhodes A, Annane D, Gerlach H, Opal SM, et al. Surviving Sepsis Campaign: International guidelines for management of severe sepsis and septic shock, 2012. Intensive Care Med. 2013;39:165–228.

22. Patel SJ, Saiman L, Duchon JM, Evans D, Fergy YH, Larson E. Development of an antimicrobial stewardship intervention using a model of actionable feedback. Interdiscip Perspect Infect Dis. 2012;2012:150367.

23. Gauthier TP, Lantz E, Heyliger A, Francis SM, Smith L. Internet-Based Institutional Antimicrobial Stewardship Program Resources in Leading US Academic Medical Centers. Clin Infect Dis. 2014;58:69-77.

24. Ashiru-Oredope D, Budd EL, Bhattacharya A, Din N, McNulty CAM, Micallef C, et al. Implementation of antimicrobial stewardship interventions recommended by national toolkits in primary and secondary healthcare sectors in England: TARGET and Start Smart Then Focus. J Antimicrob Chemother. 2016;71:1408-14.

25. Nguyen CT, Huang AM, Nagel JL. Improving antibiotic use through antimicrobial stewardship interventions upon discharge. Infect Control Hosp Epidemiol. 2019;40:1327.

29. Jones JM, Leedahl ND, Losing A, Carson PJ, Leedahl DD. Pilot study for antimicrobial stewardship post-discharge. J Pharm Pract. 2017;31(7):897190017699775.

30. Cao H, Phe K, Laine GA, Russo HR, Putney KS, Tam VH. An institutional review of antimicrobial stewardship interventions. J Glob Antimicrob Resist. 2016;6:75-77.

31. Badia JM, Casey AL, Petrosillo N, Hudson PM, Mitchell SA, Crosby C. Impact of surgical site infection on healthcare costs and patient outcomes: A systematic review in six European countries. J Hosp Infect. 2017:96:1–15.

32. Schmitt C, Lacerda RA, Turrini RNT, Padoveze MC. Improving compliance with surgical antibiotic prophylaxis guidelines: A multicenter evaluation. Am J Infect Control. 2017;45:1111–1115.

33. Abdel-Aziz A, El-Menyar A, Al-Thani H, Zarour A, Parchani A, Asim M, et al. Adherence of surgeons to antimicrobial prophylaxis guidelines in a tertiary general hospital in a rapidly developing country. Adv Pharmacol Sci. 2013;2013:1–6.

34. Ruscelli P, Renzi C, Polistena A, Sanguinetti A, Avenia N, Popivanov G, et al. Clinical signs of retroperitoneal abscess from colonic perforation. Medicine. 2018;97:e13176.

35. SNLG17. Antibiotico profilassi perioratoria nell’adulto LINEA GUIDA. Accessed 20 March 2021 Available:https://www.anmdo.org/wp-content/uploads/2016/10/Linee-guida-Antibiotico-profilassi-perioratoria-nelladulto.pdf

36. Berrios-Torres SI, Umscheid CA, Bratzler DW, Leas B, Stone EC, Kelz RR, et al. Centers for Disease Control and Prevention Guideline for the Prevention of Surgical Site Infection, 2017. JAMA Surg. 2017;152(8):784-791.

37. Scottish Intercollegiate Guidelines Network. Antibiotic prophylaxis in surgery. Accessed 20 March 2021 Available:http://www.sign.ac.uk/pdf/sign104.pdf

38. Tiri B, Bruzzzone P, Priante G, Sensi E, Costantini M, Vennelli C, et al. Impact of antimicrobial stewardship interventions on appropriateness of surgical antibiotic use/healthcare/pdfs/core-elements.pdf

Ahmed et al., JPRI, 33(23B): 62-71, 2021; Article no. JPRI.67230

Accessed 20 March 2021 Available:https://www.cdc.gov/antibiotic-use/healthcare/pdfs/core-elements.pdf

20. Tang SJ, Gupta R, Lee JI, Majid AM, Patel P, Efird L, et al. Impact of hospitalist-led interdisciplinary antimicrobial stewardship interventions at an Academic Medical Center. Jt Comm J Qual Patient Saf. 2019;45:207-216.

21. Dellinger RP, Levy MM, Rhodes A, Annane D, Gerlach H, Opal SM, et al. Surviving Sepsis Campaign: International guidelines for management of severe sepsis and septic shock, 2012. Intensive Care Med. 2013;39:165–228.

22. Patel SJ, Saiman L, Duchon JM, Evans D, Fergy YH, Larson E. Development of an antimicrobial stewardship intervention using a model of actionable feedback. Interdiscip Perspect Infect Dis. 2012;2012:150367.

23. Gauthier TP, Lantz E, Heyliger A, Francis SM, Smith L. Internet-Based Institutional Antimicrobial Stewardship Program Resources in Leading US Academic Medical Centers. Clin Infect Dis. 2014;58:69-77.

24. Ashiru-Oredope D, Budd EL, Bhattacharya A, Din N, McNulty CAM, Micallef C, et al. Implementation of antimicrobial stewardship interventions recommended by national toolkits in primary and secondary healthcare sectors in England: TARGET and Start Smart Then Focus. J Antimicrob Chemother. 2016;71:1408-14.

25. Nguyen CT, Huang AM, Nagel JL. Improving antibiotic use through antimicrobial stewardship interventions upon discharge. Infect Control Hosp Epidemiol. 2019;40:1327.

26. Anderson DJ, Watson S, Moehring RW, Komarow L, Finnemeyer M, Arias RM, et al. Feasibility of core antimicrobial stewardship interventions in community hospitals. JAMA Netw Open. 2019;2:e199369.

27. Atkins L, Chadborn T, Bondaronek P, Ashiru-Oredope D, Beech E, Herd N, et al. Content and mechanism of action of national antimicrobial stewardship interventions on management of respiratory tract infections in primary and community care. Antibiotics (Basel). 2020;9:512.
prophylaxis: How to improve. Antibiotics. 2020;9:168.
39. Pardo J, Klinker KP, Borgert SJ, Butler BM, Giglio PG, Rand KH. Clinical and economic impact of antimicrobial stewardship interventions with the Film Array blood culture identification panel. Diagn Microbiol Infect Dis. 2016;84:159-64.
40. Niwa T, Yonemamari J, Hayama N, Fujibayashi A, Ito-Takeichi S, Suzuki K, et al. Clinical impact of matrix-assisted laser desorption ionization-time of flight mass spectrometry combined with antimicrobial stewardship interventions in patients with bloodstream infections in a Japanese tertiary hospital. Int J Clin Pract. 2019;73:e13332.
41. Bates J, Francis NA, White P, Gillespie D, Thomas-Jones E, Breen R, et al. General practitioner use of a C-reactive protein point-of-care test to help target antibiotic prescribing in patients with acute exacerbations of chronic obstructive pulmonary disease (the PACE study): Study protocol for a randomised controlled trial. Trials. 2017;18:442.
42. Gillespie D, Francis NA, Carrol ED, Thomas-Jones E, Butler CC, Hood K. Use of co-primary outcomes for trials of antimicrobial stewardship interventions. Lancet Infect Dis. 2018;18:595-597.
43. Hecker MT, Son AH, Murphy NN, Sethi AK, Wilson BM, Watkins RR, et al. Impact of syndrome-specific antimicrobial stewardship interventions on use of and resistance to fluoroquinolones: An interrupted time series analysis. Am J Infect Control. 2019;47:869-875.
44. Society of Infectious Diseases Pharmacists. Antimicrobial Stewardship: A Certificate Program for Pharmacists. Accessed 20 March 2021 Available: http://www.sidp.org/Default.aspx?pageld=1442823
45. Vlek AL, Bonten MJ, Boel CE. Direct matrix-assisted laser desorption ionization time-of-flight mass spectrometry improves appropriateness of antibiotic treatment of bacteremia. PloS One. 2012;7:e32589.
46. Huang AM, Newton D, Kunapuli A, Gandhi TN, Washer LL, Isip J, et al. Impact of rapid organism identification via matrix-assisted laser desorption/ionization time-of-flight combined with antimicrobial stewardship team intervention in adult patients with bacteremia and candidemia. Clin Infect Dis. 2013;57:1237–1245.
47. Holtzman C, Whitney D, Barlam T, Miller NS. Assessment of impact of peptide nucleic acid fluorescence in situ hybridization for rapid identification of coagulase-negative staphylococci in the absence of antimicrobial stewardship intervention. J Clin Microbiol. 2011;49:1581–1582.
48. Reed EE, West JE, Keating EA, Pancholi P, Balada-Llasat JM, Mangino JE, et al. Improving the management of candidemia through antimicrobial stewardship interventions. Diagn Microbiol Infect Dis. 2014;78:157-161.
49. Jones KA, Watson M, Jacob JT, Wiley Z. Antimicrobial stewardship interventions to minimize healthcare worker exposure to SARS-CoV-2. Infect Control Hosp Epidemiol. 2020;1-2.
50. Avdic E, Wang R, Li DX, Tamma PD, Shulder SE, Carroll KC, et al. Sustained impact of a rapid microarray-based assay with antimicrobial stewardship interventions on optimizing therapy in patients with Gram-positive bacteraemia. J Antimicrob Chemother. 2017;72:3191-3198.
51. Patton A, Davey P, Harbarth S, Nathwani D, Sneddon J, Marwick CA, et al. Impact of antimicrobial stewardship interventions on Clostridium difficile infection and clinical outcomes: Segmented regression analyses. J Antimicrob Chemother. 2018;73:517-526.
52. Staub MB, Ouedraogo Y, Evans CD, Katz SE, Talley PP, Kainer MA, et al. Analysis of a high-prescribing state’s 2016 outpatient antibiotic prescriptions: Implications for outpatient antimicrobial stewardship interventions. Infect Control Hosp Epidemiol. 2020;41:135-142.
53. Flett KB, Bousvaros A, Carpenter J, Millrinne CE, Martin P, Sandora TJ, et al. Reducing redundant anaerobic therapy through spaced education and antimicrobial stewardship interventions. J Pediatr Inf Dis Soc. 2018;7:317-322.
54. Beganovic M, Costello M, Wieczorkiewicz SM. Effect of Matrix-Assisted Laser Desorption Ionization-Time of Flight Mass Spectrometry (MALDI-TOF MS) Alone versus MALDI-TOF MS combined with real-time antimicrobial stewardship interventions on time to optimal antimicrobial therapy in patients with
positive blood cultures. J Clin Microbiol. 2017;55:1437-1445.
55. Shallcross L, Lorencatto F, Fuller C, Tarrant C, West J, Traina R, et al. An interdisciplinary mixed-methods approach to developing antimicrobial stewardship interventions: Protocol for the Preserving Antibiotics through Safe Stewardship (PASS) Research Programme. Wellcome Open Res. 2020;5.
56. Dilworth TJ, Rose WE, Sakoulas G, Bayer AS. Dissecting out the direct impacts of large-scale antimicrobial stewardship interventions on clinical outcomes: Can confounding be overcome? Clin Infect Dis. 2017;65:1956-1957.

© 2021 Ahmed et al.; This is an Open Access article distributed under the terms of the Creative Commons Attribution License (http://creativecommons.org/licenses/by/4.0), which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

Peer-review history:
The peer review history for this paper can be accessed here:
http://www.sdiarticle4.com/review-history/67230