Supplementary Table S1 – Successful ASPs introduced among hospitals in low- and middle-income countries to improve antibiotic prescribing

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| **Country and year** | **Intervention and aim** | **Impact of the Intervention** |
| Kenya, 2013 [1] | Activities included developing, implementing and monitoring a policy in the hospital to improve post-operative prescribing of antibiotics among patients undergoing surgical operations**Aim**: Improve antibiotic prescribing for SAP and reduce costs | * Appreciable improvement in reducing extensive post-operative prescribing of antibiotics to 40% of operations within the first week; lowered to 10% by week 6 following the policy implementation (p< 0.0001)
* Overall, net reduction in the costs for IV antibiotics and associated consumables used to prevent SSIs by approximately, US$2.50/operation
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| Kenya, 2014 [2] | Principally education to key stakeholders to enhance the use of oral vs. IV metronidazole including education, audit and feedback.**Aim**: Increase the use of oral vs. IV metronidazole | * Post implementation audit showed an increase of more than 40% compliance in all the four criteria utilized to assess an increase in oral use, i.e. oral metronidazole used in preference to IV; for each IV administration records must indicate why this route was used and the need re-examined daily. Finally, for each prescription of IV metronidazole there must be a switch to oral tablets after a significant improvement in the patient’s condition and the records showing that patients are able to tolerate oral medication
* As a result, reduced costs, patient discomfort and possible iatrogenic infections
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| South Africa, 2016 [3] | * Activities included initial training sessions with key stakeholders in each hospital discussing the five process measures that would subsequently be audited by pharmacists in each hospital
* Each pharmacist was required to undertake audits of the five measures in their hospitals including cultures not performed before starting empiric treatment; prolonged treatment (7 and 14 days); more than 4 antibiotics prescribed concurrently and the extent of concurrent double or redundant antibiotic coverage

**Aim**: Improve antibiotic prescribing including increasing culture and sensitivity testing and reducing prolonged administration | * Combined reduction in mean antibiotic prescribing down from 101·38 to 83·04 defined daily doses/ 100 patient days (p<0·0001)
* Reductions across participating hospitals in the:
	+ Number of cultures not performed before starting empiric treatment
	+ Extent of prolonged antibiotic treatment (7 and 14 days)
	+ Prescribing of more than 4 antibiotics concurrently
	+ Prescribing of concurrent double or redundant antibiotic coverage
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| South Africa, 2017 [4] | Key activities included:* A comprehensive ASP programme comprising online education, a dedicated antibiotic prescription chart and weekly dedicated ward rounds to discuss current prescribing practices – continued over 4 years
* Pre- and post-intervention data compared to provide future guidance

**Aim**: To improve future antibiotic use in the hospital | * Total antibiotic consumption fell from 1,046 defined daily doses/1 000 patient days (pre-intervention) to 868 (first 2 years of the intervention - remaining at similar levels for the next 2 years) - improvements driven by reductions in IV antibiotic use, particularly ceftriaxone
* Laboratory testing increased over the same period
* Cost savings on antibiotics (inflation adjusted) were ZAR3.2 million over 4 years
* No significant change in mortality or 30-day readmission rates over the 4 years
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| South Africa, 2017 [5] | Key activities (driven by hospital pharmacists) included:* Testing and revising the developed guidelines and toolkits at pilot sites prior to their launch at regional workshops
* Obtaining consensus and endorsement from key professionals within each hospital to agreed quality measures - enhanced by adapting and modifying guidelines where appropriate
* Choosing at least one or more surgical procedures to audit
* Measuring compliance to agreed quality measures over a 4-week period and giving feedback

**Aim**: Implement a model utilizing existing resources in order to improve antimicrobial use for SAP  | * Significant improvement in compliance with all agreed quality measures
* SSI rate decreased by 19.7% from a mean group rate of 2.46 pre-intervention to 1.97 post-intervention (P = 0.0029)
* Timely administration of antibiotics increased to 56.4% of surgical patients (P < 0.0001) – 62.4% increase
* Antibiotic choice consistent with the guidelines increased to 95.9% of patients and the duration of prophylaxis appropriate among 93.9% of patients following the ASP
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| Kenya, Uganda, Zambia,and Zimbabwe, 2018 [6] | Activities included: * Five planned visits to each participating hospital among four African countries during the study period - supported by a range of educational tools
* Local teams identified key areas of concern with preventing SSIs; subsequently monitoring an agreed range of indicators (six pre-identified ones including skin preparation and optimal timing of prophylaxis)
* Subsequent introduction of a number of tools and agreed prescribing indicators. This alongside monitoring/ feedback to improve future prescribing

**Aim**: Improve antibiotic prescribing for the prevention of SSIs among patients in the participating hospitals | * Appropriate use of antibiotics to prevent SSIs improved from 12.8% (205/1604) at baseline to 39.1% (714/1827) in the follow-up phase (p <0·0001) among the studied hospitals
* Concurrently, the cumulative incidence of SSIs decreased from a baseline of 8.0% (129/1604) to 3.8% (70/1827) post intervention (p <0·0001)
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| Iran, 2019 [7] | * For 6 days each week, the ASP team including Infectious Disease physicians and pharmacists inspected prescribing instructions of physicians and applied daily and weekly dosing patterns for meropenem and vancomycin
* These antibiotics were purposefully selected as concerns with high prescribing rates
* The Infectious Disease pharmacist also notified key physicians of clinical microbiology laboratory findings

**Aim**: Assess the impact of the ASP on the prescribing of meropenem and vancomycin in pediatric patients | * 135 children were included in the ASP
* The levels of antimicrobial prescribing, dosing and duration of key antimicrobials prescribed were significantly improved after the ASP
* The length of hospital stay was also significantly lower after the ASP (15.6 ± 2.8 vs. 22.7 ± 1.9)
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| Kenya, 2019 [8] | * The intervention included education - a half-day training on the new Kenyan pneumonia guidelines, with physicians in all hospitals supplied with updated protocol booklets including specific pneumonia algorithms. All hospitals also received continued network support
* The two groups were:
1. Standard feedback with regular auditing and bimonthly feedback of general pediatric care
2. Enhanced feedback group – Regular auditing of agreed indicators of pneumonia care, with monthly feedback using specific feedback sheets
* Overall 2 299 childhood pneumonia admissions in the two groups

**Aim**: To determine whether providing enhanced audit and feedback might accelerate adoption of new pneumonia guidelines | * An improvement was seen in the enhanced feedback group regarding correct classification and treatment of patients with pneumonia after each round of enhanced feedback
* However, the performance declined in the standard feedback arm over time. This was attributable to consistently poor performances among four out of the six participating facilities
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| Lebanon, 2019 [9] | * The ASP, ID team, and ICU physicians approved a plan to reduce empiric prescribing of carbapenems
* In addition, to reduce the prescribing of colistin, tigecycline, or both, unless patients confirmed with or at high risk for *A. baumanii* infections as concerns with extensive resistance development
* ID physicians evaluated the clinical severity and hemody­namic stability of each patient and had the final discretion to prescribe either colistin or tigecycline

**Aim**: Evaluate the effect of an ASP involving a carbapenem-sparing regimen on ICU antimicrobial consumption, clinical outcome, and resistance patterns | * Carbapenem consumption decreased by 59% during the one-year study period
* Re­stricted antimicrobial drug consumption including carbapenems, carbapenem-sparing regimens, colistin and tigecycline dropped 637 DDD/1,000 patient-days (p<0.005) with colistin utilization decreasing by 55% post intervention
* Tigecycline consump­tion remained unchanged
* 78% decrease of *A. baumanii* isolated in spu­tum and near-elimination of *A. baumannii* carrying the *bla*oxa-23gene (over the 1-year study period
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| Nigeria, 2019 [10] | Activities included:* The development and dissemination of an agreed protocol
* Educational meetings held with key clinicians to enhance the uptake of agreed protocols combined with wall mounted posters
* Regular audit and feedback meetings using

**Aim**: To improve antibiotic prescribing by reducing the extent of extended prophylaxis to prevent SSIs. | * Patients in the post-intervention period were 5.6 times more likely to receive antibiotics within 60 minutes before the incision to prevent SSIs vs. pre-intervention (p <0.001)
* The prescribing of 3rd generation cephalosporins for SAP reduced from 29.2% in the pre-intervention period to 20.6% in the post-intervention period (P = 0.032).
* The rate of redundant antibiotic prescriptions was reduced by 19.1%
* Mean cost of SAP was reduced by $4.2/ patient (P < 0.001) after the interventions
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| Ethiopia, 2020 [11] | * 1,109 individual patients took part (707 during the intervention and 402 in the post-intervention periods)
* Principally education of key stakeholders including weekly audit meetings and immediate feedback sessions regarding antibiotic prescriptions of admitted patients
* This built on recently developed institutional guidelines and training sessions
* However, there were no feedback initiatives to remind physicians of the guidelines and their activities to date

**Aim**: Auditing of antibiotic prescriptions post intervention and the impact of the intervention | * Most commonly prescribed antibiotics were ceftriaxone, cefepime, meropenem, metronidazole and vancomycin
* 96% of the recommendations made by the Stewardship team were accepted
* However, once the intervention ceased, total antimicrobial use increased by 51.6%. Alongside this, the mean duration of treatment increased by 4.1 days/patient
* Mean hospital stay decreased during the stewardship intervention; however, increased significantly after that
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| Iran, 2020 [12] | * An ASP team consisting of 2 infectious disease (ID) specialists, 2 clinical pharmacists, a microbiologist, an information technology specialist and a hospital administrator was formed
* The combined intervention included:
* guideline revisions and the development of “antimicrobial order forms”
* information and education of key groups, regular ward rounds and intensified ID consultations and feedback

**Aim**: Evaluate the effect of the ASP in reducing antibiotic use and AMR | * Antimicrobial consumption dropped by 24.8%, 25.0%, 35.3%, 47.0%, 39.2%, 10.5% and 23.2% for amphotericin B, caspofungin, colistin, voriconazole, meropenem, imipenem, and vancomycin, respectively
* Linezolid consumption increased by 26.8% after implementing the ASP
* Expenditure of target antimicrobials decreased by 41.3% after the intervention (=0.001)
* Increased antimicrobial susceptibility of *Pseudomonas aeruginosa* after the intervention
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| Iran, 2020 [13] | Activities included infectious disease physician consultations and education in two internal disease wards to review/ confirm carbapenem use in patients within 48 hours of initiation as concerns with the overuse of carbapenems an resistance development **Aim**: Assess the impact of the ASP intervention on carbapenem prescribing | * Of the 186 consultations conducted by the ID specialists, 15% resulted in a change in antibiotic prescribing, 25% resulted in discontinuation of carbapenems, while in 60% carbapenems were continued.
* Crude mortality in the two internal medicine wards was calculated to be 2.6% with no significant change versus the previous year
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| Malawi, 2020 [14] | * Intervention in the hospital involved guidelines, posters and the application of smartphones to help with clinical decision making as well as regular PPS studies and prescriber feedback
* 503 patients were involved - 203 pre-implementation, 200 implementation phase and 100 patients post-implementation

**Aim**: Reduce extensive prescribing of third-generation cephalosporins in the hospital and associated costs with no adverse impact on mortality  | * The proportion of prescriptions for an IV 3rd generation cephalosporin fell from 80.1% of all prescriptions to 53.6% (177/330) by the last survey
* The median length of a ceftriaxone course was reduced from 5 to 4 days aided by an increase in the number of clinician reviews of prescriptions at 48-hours
* Overall annual savings from the 3 wards was estimated at US$15,000 with no change in mortality or median length of hospital stay
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| Sudan, 2020 [15] | a) Activities included:* Verbal contact by clinical pharmacists with all key surgeons involved with performing emergency caesarean sections (ECSs) on agreed updated guidelines for the use of prophylactic antibiotics in ECS to prevent SSIs
* Brochures giving details about proposed changes in prophylactic antibiotic recommendations for patients including no longer administering metronidazole (IV before cord clamping and on discharge) or oral amoxicillin‑clavulanic acid on discharge
* Subsequent auditing and feedback of the findings
1. Overall, 195 participants were included

**Aim**: Improve the rational use of prophylactic antibiotics among patients undergoing ECS  | * The hospital protocol was fully followed so no patient subsequently received either metronidazole (IV or oral) or oral amoxicillin‑clavulanic acid on discharge following the intervention
* Cost saving of 31% on antibiotics administered to prevent SSIs post intervention
* No patient in the revised administration group developed any symptoms or signs of an SSI (at days 15 and 30 post discharge)
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| Tanzania, 2020 [16] | * Activities included formal and on-job training including seminars on infection prevention and control/ evidence-based education on antimicrobial resistance and good antimicrobial prescribing practice
* 1377 women undergoing caesarean sections were enrolled, 664 in the pre-intervention phase and 713 in the post-intervention phase

**Aim**: Enhance appropriate antibiotic prescribing to prevent SSIs for patients undergoing caesarean sections | * Pre-incision antibiotic prophylaxis was administered in significantly more cases post the educational intervention (p < 0.001)
* The extent of antibiotics administered post-operatively to prevent SSIs was appreciably reduced post intervention (p < 0.001)
* The total number of SSIs decreased from 48% pre-intervention to 17% post intervention (p < 0.001)
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| South Africa, 2021 [17] | * Intervention: Education and Engineering involving regular ASP ward rounds on two surgical wards
* During the ward rounds - each condition was discussed especially concerning antibiotic selection and laboratory investigations
* In addition, potential switching from intravenous to oral agents, dose optimization and any dose adjustments in patients with renal and hepatic impairment
* 476 patients were involved - 264 at baseline vs 212 in ASP phase

**Aim**: Demonstrate a reduction in antibiotic usage (measured by the volume of antibiotic consumption following the ASP) – as a result improve overall antibiotic prescribing | * Reduction in the volume of antibiotic consumption from 739.30 DDDs/1000 to 564.93 DDDs/1000 patient days following the ASP
* Reduction in inappropriate antibiotic use from 35% to 26% of patients
* An overall increase in culture targeted therapy
* Reduction in antibiotic administration for more than one day post operatively to prevent SSIs (from 7.3% to 6.6%)
* Small (non-significant reduction) in total antibiotics administered IV (from 89.4% to 84.2%) alongside an increase in appropriate IV administration from 56.9% to 60.8%
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| Jordan, 2022 [18] | * Introduction of AMS teams in hospitals consisting of infectious disease physicians, clinical pharmacists, microbiology personnel, infection control nurses
* In one hospital, this included the IT Director and in another a quality control department staff member
* ASPs introduced to restrict the use of target antibiotics including the introduction of local guidelines

**Aim**: Assess the impact of ASPs in hospitals in Jordan | * Antibiotic susceptibility testing to appropriate antibiotics improved in both hospitals
* The incidence of ESBL positive *E. coli*, ESBL positive *Klebsiella*, and vancomycin resistant enterococcal species decreased post ASP while methicillin-resistant *Staphylococcus aureus* showed an increase in incidence during the second year of the study, although there was no change in ASP adherence
* Overall, the study emphasized the positive impact of ASPs
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| Liberia, 2022 [19] | * Multiple activities including production and dissemination of local treatment guidelines; training and regular AMS ward rounds and monitoring of agreed indicators
* Prescribing indicators included prescribing of correct antibiotics (incorporating completeness of microbiological diagnostics) as well as their dose and duration
* Indicators were assessed after AMS ward rounds and fed back to key personnel
* 620 patients overall were included in the study - 310 pre intervention and 310 post intervention

**Aim**: Assess the impact of AMS programmes with improving antibiotic prescribing in the hospital  | Improvements were seen in all studied indicators* Adherence to local guidelines improved from 34.5% of patients to 61.0% (P<0.0005)
* Correct dosing of antibiotics improved from 15.2% of patients to 36.5% (P<0.0005)
* Optimal duration of antibiotic use improved from 13.2% of patients to 31.0% (96/310)
* Proportion of patients receiving ceftriaxone reduced from 51.3% of patients to 14.2% (P<0.0005).
* Following the intervention, 79.7% of patients had samples sent for microbiological analysis to improve antibiotic prescribing
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NB: AMS = Antimicrobial Stewardship; ASP = Antimicrobial Stewardship Programme; CAP = Community Acquired Pneumonia; ECS = Emergency Caesarean Sections; ICU= Intensive Care Unit; SSI= Surgical Site Infection

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