**Supplemental material**

Supplemental Tables 1-4 are based on a hypothetical, quasi-experimental implementation-effectiveness trial across a network of 10 Emergency Departments (EDs). The primary goal of the trial is to reduce antibiotic-prescribing for viral acute respiratory tract infections (ARIs).

* The evidence-based practice being implemented is withholding antibiotics for ARIs that are likely viral in etiology (i.e. uncomplicated ARIs such as acute bronchitis in the absence of chronic lung disease, upper respiratory tract infections, and nasopharyngitis).
* In this hypothetical example, the implementation strategies being used are 1) audit-and-feedback of how frequently ED clinicians prescribe antibiotics for viral ARIs and 2) obtaining formal letters of a clinician’s commitment to judiciously prescribe antibiotics for ARIs. Though not described, other important strategies to include would be 1) local champions and 2) education of both clinicians and patients on optimal antibiotic use.
* The primary clinical effectiveness outcome of this trial would be the percentage of patients visits for uncomplicated ARIs that resulted in an antibiotic prescription. Secondary outcomes will be total antibiotic prescriptions per 1,000 patient-visits and several 30-day outcomes: return ED visits, hospital admissions, and *C. difficile* infections.
* Implementation outcomes that could be measured are shown in Supplemental Table 1 (see “Implementation outcome affected”).
* Supplemental Tables 2-4 show how this implementation-effectiveness trial could be conceptualized within each type of implementation science framework (i.e. process, determinant, and evaluation).

**Supplemental Table 1. Requirements for measuring and reporting implementation strategies**

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| **Aspects of the implementation strategy** | **Description of reporting requirements** | **Description of a hypothetical, quasi-experimental implementation-effectiveness trial in a network of Emergency Departments (EDs) with the goal of reducing antibiotic-prescribing for viral acute respiratory tract infections (ARIs)** | |
| **Implementation strategy #1** | **Implementation strategy #2** |
| **Name and definition** | Name the strategy using common nomenclature. | Audit-and-feedback | Obtain formal commitments |
| **Definition** | Define the strategy and describe its operational elements. | Based on established methodology, the project team will calculate an ARI metric for each ED clinician.1 Each clinician will be shown his/her performance on the ARI metric in comparison to local peers. | Each ED clinician will be asked to sign a commitment letter written at the eighth-grade reading level. The text will be consistent with prior published work.3 |
| **Justification** | Why was the specific implementation strategy chosen? | Peer group opinion is a strong predictor of an ED clinician’s decision to prescribe antibiotics, and personalized feedback to clinicians can be helpful.2 | ED clinicians who have committed publicly to judicious antibiotic-prescribing may be less likely to give antibiotics for viral ARI.3 |
| **The actor** | Who enacts the strategy? | The project coordinator will organize the data collected from monthly electronic audits of ED clinicians and will send the audit results via e-mail from the e-mail account of each site’s champion. | The clinician champion at each participating ED will ask colleagues to sign the commitment letter. |
| **The action** | What actions, steps or processes will be enacted? | Every month, each site’s champion will send each ED clinician an e-mail with their audit data from the prior month with an anonymous comparison to peers. The wording of each e-mail will be consistent with the MITIGATE toolkit.1 | A framed 18x24 inch copy of the commitment letter will be hung in each clinician’s examination room. A photograph of the clinician will be featured on the letter. The letter will be hung so that it is in the direct line of vision of a patient sitting on the examination table. |
| **Action target** | What are the targets of the strategy, based on established implementation frameworks? | Based on the CFIR framework, this strategy will address two domains: characteristics of the ED clinicians and the inner setting (e.g. culture, goals and feedback, access to knowledge and information). | Based on the CFIR framework, this strategy will address three domains: inner setting (e.g. culture, implementation climate), characteristics of ED clinicians (e.g. self-efficacy, knowledge and beliefs), and process (e.g. champions, engaging) |
| **Temporality** | When is the strategy used? | Feedback is provided during the first week of every month | The commitment letters will be hung at the beginning of the implementation process. |
| **Dose** | How frequently is the strategy used? | Feedback is given to each clinician on a monthly basis. To ensure the clinician reviewed the feedback, a read receipt will be requested. | The commitment letters will remain hung for the entire trial period unless the clinician requests removal. Clinicians will be allowed to sign a commitment letter after trial initiation. |
| **Implementation outcome affected** | Which implementation outcome(s) will be measured to assess the strategy? | Acceptability, adoption, feasibility, fidelity, implementation cost | Acceptability, adaptation, adoption, feasibility, fidelity, implementation cost |
| Effectiveness outcomes will include the ARI metric, total antibiotic prescriptions per patient-visits, and 30-day outcomes (return ED visits, hospital admissions, C. difficile infections) | |

Abbreviations: acute respiratory tract infection (ARI); CFIR Consolidated Framework for Implementation Research; Emergency Department (ED)

1. May LY, Yadav K, Gaona SD, et al. MITIGATE antimicrobial stewardship toolkit: a guide for practical implementation in adult and pediatric emergency department and urgent care settings, 2018. Society for Healthcare Epidemiology of America website http://shea-online.org/images/prioritytopics/ MITIGATE\_TOOLKIT\_final.pdf. Published 2018. Accessed February 18, 2021.
2. May L, Gudger G, Armstrong P, et al. Multisite exploration of clinical decision-making for antibiotic use by Emergency Medicine providers using quantitative and qualitative methods. *Infect Control Hosp Epidemiol* 2014; 35: 1114-1125.
3. Meeker D, Knight TK, Friedberg MW, et al. Nudging guideline-concordant antibiotic prescribing: a randomized clinical trial. *JAMA Intern Med* 2014; 174(3): 425-431.

**Supplemental Table 2. Stepwise implementation plan for a hypothetical implementation-effectiveness trial in an Emergency Department network with the goal of reducing antibiotic use in viral ARIs, based on Provonost’s 4E Process Theory**1

1. **Summarize the evidence about the benefits and harms of antibiotic use for viral ARIs**

**2. Identify local barriers to implementation**

* Review the published literature to understand reasons for the evidence-practice gap and barriers/facilitators to implementing stewardship strategies in ED settings
* Interview ED clinicians and patients about their attitudes and beliefs surrounding antibiotic use for ARIs
* Engage all local stakeholders to identify potential barriers and facilitators to prescribing antibiotics more judiciously for ARIs

**3. Measure performance**

* Select performance measures (e.g. the frequency at which an ED clinician prescribes an antibiotic for a patient with an ARI)
* Select safety outcomes (e.g. return visits, *Clostridioides difficile* infections)
* Measure baseline performance

**4. Ensure all clinicians receive the intervention**2

1. **Engage:** Explain to ED clinicians why judicious antibiotic use is important
2. **Educate:** Share evidence showing the potential harms of unnecessary antibiotic use
3. **Execute:** Design an implementation toolkit that targets barriers identified in step 2
4. **Evaluate:** Assess performance measures and safety outcomes at regular intervals; provide feedback to ED clinicians and, as needed, repeat steps 4a—4d
5. knowledge translation. *BMJ*. Oct 6 2008;337:a1714.
6. Pronovost PJ, Berenholtz SM, Needham DM. Translating evidence into practice: a model for large scale knowledge translation. *BMJ*. Oct 6 2008;337:a1714.
7. In this example, the intervention would consist of a group of antibiotic stewardship practices used in combination to address the specific evidence-practice gap.

**Supplemental Table 3. Selected CFIR determinants of implementation applied to a hypothetical implementation-effectiveness trial in an Emergency Department network with the goal of reducing antibiotic use in viral ARIs**1,2

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| **Construct** | **Short Description in relation to the hypothetical trial** |
| **Intervention characteristics** |  |
| Evidence Strength and Quality | Clinicians’ and patients’ perceptions about the scientific evidence that supports not prescribing antibiotics for viral ARIs |
| Relative Advantage | Clinicians’ and patients’ perceptions of the benefit of withholding versus prescribing antibiotics for viral ARIs |
| **Outer Setting** |  |
| Peer pressure | Competitive pressure to prescribe antibiotics more judiciously because other peer organizations are doing so |
| External policies and incentives | How the Joint Commission’s requirements for antibiotic stewardship in ambulatory care influence antibiotic-prescribing behaviors |
| **Inner Setting** |  |
| Culture | Norms and values of an organization about judiciously prescribing antibiotics |
| Relative priority | ED clinicians’ shared perception of whether judiciously prescribing antibiotics is important to their organization |
| **Characteristics of Individuals** |  |
| Self-efficacy | An ED clinician’s belief in his/her own ability to withhold antibiotics for viral ARIs |
| Individual Stage of Change | An ED clinician’s readiness to start prescribing antibiotics more judiciously for ARIs |
| **Process** |  |
| Opinion leaders | Individuals within the organization who influence the attitudes and beliefs of ED clinicians about using antibiotics more judiciously for ARIs |
| Executing | Whether the implementation strategies were carried out as planned |

1. These determinants are based on the domains of the Consolidated Framework for Implementation Research (https://cfirguide.org).
2. Each domain could be explored through semi-structured interviews with ED clinicians, patients and other key stakeholders. These interviews could be performed during the pre-implementation period to inform the selection and design of the implementation strategies. Alternatively, the domains could be assessed during the trial itself to guide adaptations to the implementation process. A third option would be to assess these determinants after the trial is completed to help understand barriers and facilitators to the project’s success.

**Supplemental Table 4. Applying the RE-AIM implementation framework to a hypothetical implementation-effectiveness trial in an Emergency Department network with the goal of reducing antibiotic use in viral ARIs**

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| **Dimension** | **Definition**1 | **Measurement** |
| **Reach** | The absolute number, proportion and representativeness of individuals who are willing to participate in a given initiative or program, and reasons why they do or do not participate  Who actually participates or is exposed to the initiative? | Monitor the number and proportion of ED clinicians who kept their commitment letters hung for the entire initiative and continued to acknowledge via read receipts the monthly e-mail feedback they received on the ARI metric. Using baseline clinician data, describe differences in ED clinicians who participated versus did not participate. |
| **Effectiveness** | The effect of the initiative on important individual outcomes, such as clinical events, quality of life, and economic outcomes | Using electronic data extracted from the medical record, measure the proportion of ARI visits that resulted in an antibiotic prescription as well as safety outcomes (e.g. return visits, hospitalization). |
| **Adoption** | The absolute number, proportion and representativeness of settings and agents who are willing to start a program and why they are willing to start it  Where is the program applied and who applied it? | Report the number of unique ED sites asked to participate in the study and the number that agreed to participate in the study. Describe differences between these two groups. |
| **Implementation** | Fidelity to the key elements of an evidence-base practice, including consistency of delivery as intended and the time and cost of the program  How consistently was the program delivered? How was it adapted to each setting? How much did it cost? Why did it achieve the observed result? | Measure acceptability using semi-structured interviews with ED clinicians. Assess fidelity by interviewing the project coordinator and local champions. Measure implementation cost by having the project coordinator and local champions track the time committed to project activities on a weekly basis. |
| **Maintenance** | The extent to which a program or policy becomes institutionalized or part of the routine organizational practices and policies.  How long are the results of the program or policy sustained? | Perform a telephone interview with each site’s local champion 6 months after the study’s conclusion to determine 1) if clinicians kept their commitment levels hung once the organized initiative ended and 2) if sites developed their own local process for continuing to provide clinicians feedback on their antibiotic-prescribing. |

1. All definitions are taken from https://www.re-aim.org