Research Brief



Implementation of Outpatient Automated Stewardship Information System (OASIS[©]) audit and feedback in 2 healthcare systems

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(Received 22 May 2024; accepted 31 July 2024)

Introduction

Providing feedback to clinicians on their prescribing over time and compared to their peers has been highly effective in reducing unnecessary antibiotic prescribing.¹ However, obtaining data in the outpatient setting is resource intensive and often cost prohibitive.² Outpatient Automated Stewardship Information System (OASIS[©]) was developed to alleviate these barriers.^{2,3} OASIS[®] has been shown to increase guideline-concordant durations of therapy for acute otitis media (AOM).³ It uses common statistical software (R, R Foundation for Statistical Computing, Vienna, Austria) to abstract data from the electronic health record (EHR), analyze, and email feedback reports to clinicians. The code is free, and open-source and allows for automation;⁴ thus, continuous investment is minimal, and organizations need only invest resources in the initial setup. In this project, we aimed to assess the adaptations needed to implement OASIS[®] across 2 healthcare systems for 4 respiratory metrics and, secondarily, assess the proportion of clinicians that viewed the reports and whether there were changes in prescribing associated with OASIS[©] implementation.

Methods

OASIS[®] was implemented at Denver Health and Hospital Authority (DHHA) and Children's Hospital Colorado (CHCO) from July 2022 to October 2023. Both organizations use Epic[®] EHR (Verona, WI) but have different versions and builds. The intervention included the generation of individualized audit and feedback reports for clinicians that displayed their prescribing over time and compared to their peers. Targeted metrics included (1)

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PRIOR PRESENTATION OF WORK: The results of this study were presented in a poster presentation at the Society for Healthcare Epidemiology of America conference in April 2024.

Cite this article: MacBrayne CE, Keith A, Poole NM, *et al.* Implementation of Outpatient Automated Stewardship Information System (OASIS[®]) audit and feedback in 2 healthcare systems. *Antimicrob Steward Healthc Epidemiol* 2024. doi: 10.1017/ash.2024.412

antibiotics prescribed for acute respiratory tract infections (ARTI),^{5–7} (2) antibiotics prescribed for ARTIs for which antibiotics are never indicated,^{6,7} (3) first-line antibiotic therapy for AOM,⁸ and (4) 5-day durations of therapy for children 2 years of age and older with AOM.³

The primary outcome was adaptations needed to implement OASIS[®]. An evaluation utilizing the Framework for Reporting Adaptations and Modifications to Evidence-based Implementation Strategies (FRAME-IS) was conducted⁹ (Table 1). Secondary outcomes included fidelity, time to set up and maintain the program, barriers and facilitators to implementation, and changes in antibiotic prescribing for each metric (Supplemental Methods).

This project was reviewed and approved by the Organizational Research Risk and Quality Improvement Review Panel at CHCO and the Quality Improvement Review Committee at DHHA.

Results

OASIS[®] was implemented across 11 clinics involving 195 clinicians and 29,186 patient encounters. Five rounds of reports were issued (Supplementary Table 1). Adaptations were necessary for implementation (Table 1), most of which required data analytic expertise. Adaptations included the inability to automate OASIS[®] in organizations that did not utilize an R server but operated R on individual computers. In this case, the program was re-run each month (estimated time 10 minutes). Second, 1 site had difficulty obtaining accurate email addresses from the EHR. In this case, a list of addresses needed to be generated manually. Finally, clinicians requested changes to the report formatting to improve readability (Supplement). The program had high fidelity and significantly improved antibiotic prescribing at CHCO while maintaining good baseline practices at DHHA (Supplement).

Discussion

We successfully utilized OASIS[®] to distribute recurrent individualized audit and feedback reports for clinicians. The program demanded adjustments (8 at each site, with an additional 3 at

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 Table 1. Adaptations needed for OASIS[©] implementation using the FRAME-IS framework

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¹Electronic health record.

²Children's Hospital of Colorado.

³Denver Health and Hospital Authority.

CHCO), with an initial setup time ranging from 1 to 6 hours. Successful integration relied on data analytical skills for code changes in the programming language and analyst access to EHR data. Findings suggest that OASIS[®] could present a cost-effective approach to antimicrobial stewardship for health systems with adequate data analytics expertise.

Having a team member skilled in informatics and/or coding was essential. We found that the RStudio packages needed to run reports, while free, may be unfamiliar to some analysts. Notably, the code effectively abstracted accurate data for diagnoses and antibiotics and did not require modification despite participating organizations having substantially different Epic[®] builds.

Although we anticipated the need for adaptations to the code, we were surprised by the clinician and health-system-level adaptations that were required. Institutions had differing security requirements and definitions of Health Insurance Portability and Accountability Act (HIPAA) compliance. For one organization, reports could not depict data for prescribers with fewer than 10 encounters, and some clinicians had their institutional emails forwarded to a personal address and therefore could not receive reports due to HIPAA restrictions. Adaptations were made to ensure that all clinicians ultimately used a compliant email address. In addition, it was noted at CHCO that the read receipt verification prompt was easily bypassed, which led to lower readership because of clinicians not clicking "yes" to having read the report on the pop-up prompt.

This project had several strengths, including the ability to use mixed methods to evaluate adaptations needed for effective implementation of OASIS[®] and the ability to assess the implementation of 4 relevant metrics. This project also had limitations. We were only able to assess adaptations across 2 health systems that use a similar her; therefore, results may not be generalizable to other systems. Additionally, our evaluation was limited to sites that had some level of data analytic and informatics expertise. Thus, the complexity of implementing OASIS[®] in sites with limited expertise in using R or accessing the electronic data warehouse may differ. We also could not assess OASIS's[®] long-term impact on prescribing due to the short analysis period.

In conclusion, the implementation of OASIS[®] required contention with system diversity and knowledge gaps in informatics and antibiotic stewardship. Despite these challenges, it proved valuable for monitoring and reporting antimicrobial prescribing. OASIS[®] could be effectively disseminated to other health systems given the limited time and resources required for adaptations, setup, and monitoring.

Supplementary Material. The supplementary material for this article can be found at https://doi.org/10.1017/ash.2024.412.

Acknowledgments.

Author contributions. Dr MacBrayne: Investigation, supervision, project administration, writing—original draft, writing—review and editing.

Ms. Amy Keith and Ms. Theresa Morin: Investigation, project administration, writing—review and editing.

Dr Nicole Poole: Investigation, supervision, project administration, writing—review and editing.

Dr Cory Hussain and Mr. Joshua Tucker: Investigation, project administration, formal analysis, software, writing-review and editing.

Dr Jenkins: Supervision, writing-review and editing.

Dr Frost: Funding acquisition, conceptualization, investigation, project administration, supervision, writing—review and editing.

Financial support. Funding was provided by Pew Charitable Trusts (award number 35761). HF received salary support from the Eunice Kennedy Shriver National Institute of Child Health and Human Development of the National Institutes of Health (award number K23HD099925). The content is solely the responsibility of the authors and does not necessarily represent the official views of the National Institutes of Health. The funder had no role in the design or interpretation of the study.

Competing interests. The authors have no conflicts of interest to disclose.

References

- Sanchez GV, Fleming-Dutra KE, Roberts RM, Hicks LA. Core elements of outpatient antibiotic stewardship. MMWR Recomm Rep Morb Mortal Wkly Rep Recomm Rep 2016;65:1–12. doi: 10.15585/mmwr.rr6506a1
- Frost HM, Andersen LM, Fleming-Dutra KE, Norlin C, Czaja CA. Sustaining outpatient antimicrobial stewardship: Do we need to think further outside the box? *Infect Control Hosp Epidemiol* 2020;41:382–384. doi: 10.1017/ice. 2019.366
- Frost HM, Lou Y, Keith A, Byars A, Jenkins TC. Increasing guidelineconcordant durations of antibiotic therapy for acute otitis media. J Pediatr 2022;240:221–227.e9. doi: 10.1016/j.jpeds.2021.07.016
- 4. Frost Labs. OASIS, Stewardship Simplified. Accessed September 1, 2023. www.oasisstewardship.org
- National Committee for Quality Assurance. Appropriate Treatment for Upper Respiratory Infection (URI). Accessed October 23, 2023. https://www. ncqa.org/hedis/measures/appropriate-treatment-for-upper-respiratoryinfection/
- Bizune D, Tsay S, Palms D, *et al.* Regional variation in outpatient antibiotic prescribing for acute respiratory tract infections in a commercially insured population, United States, 2017. *Open Forum Infect Dis* 2023;10:ofac584. doi: 10.1093/ofid/ofac584
- King LM, Tsay SV, Hicks LA, Bizune D, Hersh AL, Fleming-Dutra K. Changes in outpatient antibiotic prescribing for acute respiratory illnesses, 2011 to 2018. *Antimicrob Steward Healthc Epidemiol ASHE* 2021;1:1–8. doi: 10.1017/ash.2021.230
- Lieberthal AS, Carroll AE, Chonmaitree T, et al. The diagnosis and management of acute otitis media. *Pediatrics* 2013;131:e964–999. doi: 10.1542/peds.2012-3488
- Miller CJ, Barnett ML, Baumann AA, Gutner CA, Wiltsey-Stirman S. The FRAME-IS: a framework for documenting modifications to implementation strategies in healthcare. *Implement Sci IS* 2021;16:36. doi: 10.1186/s13012-021-01105-3