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Implementing Antimicrobial Stewardship in Long-term Care Settings: An Integrative Review Using a Human Factors Approach

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Implementing effective antimicrobial stewardship in long-term care facilities (LTCFs) is associated with challenges distinct from those faced by hospitals. LTCFs generally care for elderly populations who are vulnerable to infection, have prescribers who are often off-site, and have limited access to timely diagnostic testing. Identification of feasible interventions in LTCFs is important, particularly given the new requirement for stewardship programs by the Centers for Medicare and Medicaid Services (CMS). In this integrative review, we analyzed published evidence in the context of a human factors engineering approach as well as educational interventions to understand aspects of multimodal interventions associated with the implementation of successful stewardship programs in LTCFs. The outcomes indicate that effective antimicrobial stewardship in long-term care is supported by incorporating multidisciplinary education, tools integrated into the workflow of nurses and prescribers that facilitate review of antibiotic use, and involvement of infectious disease consultants.

Keywords. antimicrobial stewardship; nursing home; long-term care; human factors; elderly.

In September 2014, the Obama Administration issued the Executive Order "Combating Antibiotic-Resistant Bacteria" [1], prompting the Centers for Medicare and Medicaid Services (CMS) to propose regulatory changes that will require antimicrobial stewardship activities in long-term care facilities (LTCFs) [2]. LTCFs include several settings that provide skilled nursing and residential care, such as long-term acute care hospitals (LTACHs), assisted living, home healthcare, and nursing homes. Recent reviews of this topic indicate that the antimicrobial stewardship interventions described in the literature are multimodal and generally incorporate a structured educational component [3–5]. They also call for further research to identify effective implementation strategies [3–5].

Effective antimicrobial stewardship requires complex and interdisciplinary interventions that address both people and healthcare systems in which they work. The Systems Engineering Initiative for Patient Safety (SEIPS) is a human factors model that uses an engineering approach to patient safety by guiding work system redesign and improvement efforts [6]. Human factors engineers consider complex work systems, applying their knowledge of human limitations and abilities to reduce the safety risks to patients due to human error and to improve the overall work system in which care is provided [7, 8]. The SEIPS model proposes that the following 5 work system components continuously interact and influence one another: tools and technologies, tasks, organizational conditions, person(s), and the physical environment (Table 1) [6]. Changes to any or multiple aspects of these components may either positively or negatively affect the resulting processes, and therefore patient, professional, or organizational outcomes. Hence, this model can be useful to organizations developing and implementing an antimicrobial stewardship intervention by considering the complex and dynamic nature of LTCFs and contextual factors unique to that healthcare setting.Here, we use an integrative literature review to analyze antimicrobial stewardship interventions in LTCFs within the framework of a human factors engineering approach to identify those aspects of multimodal interventions most likely to support effective implementation.

METHODS

Using integrative review methodology [9], we searched PubMed for peer-reviewed medical literature describing antimicrobial stewardship interventions in LTCFs. Iterative searching of

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Table 1. Description of 5 Work System Components in the Systems Engineering Initiative for Patient Safety Model

Work System Component	Description	Examples
Tools and technologies	Objects that individuals use to carry out their work	- Alert on an electronic health record - Pocket card describing antibiotic prescribing guidelines
Tasks	Specific actions within a larger work process	- Act of administering a medication - Checklist of antibiotic monitoring criteria that must be filled out by a pharmacist daily prior to distributing medications
Organization	Structures put in place to organize time, space, or resources; cultural infrastructure of the facility or communication between individuals.	- Incentive program for following antibiotic prescribing guidelines - Support from stakeholders for promotion of antibiotic stewardship program
Person(s)	Individual characteristics of those involved in the work system	- Knowledge, expertise, or training of nursing home staff
Environment	Physical internal or external environment where the work is done.	- Physical placement of an educational poster in a common work area

the identified publications and their references informed the final search terms (Supplementary Appendix 1). Two authors (M. J. K., R. L. P. J.) independently reviewed all titles and abstracts. Inclusion criteria were primary research studies published in English that described antimicrobial stewardship interventions in LTCFs (skilled nursing facilities, nursing homes, or LTACHs) and that used quantitative outcome measures. Exclusion criteria were studies based in ambulatory or acute care facilities, those that did not include an antimicrobial stewardship intervention, or those that did not use quantitative measures to assess outcomes. Studies determined to be possibly eligible based on the title and abstract were included for full text review for final assessment of inclusion and exclusion criteria. The same reviewers examined the bibliographies of the included studies as well as the review articles selected in the initial literature search. Data evaluation considered the study design, focus on a specific infectious syndrome (eg, urinary tract infection or pneumonia), and quantitative outcome measures. Quality assessment was performed using established quality assessment tools [10]. Two authors (M. J. K., R. L. P. J.) independently assessed risk of bias using these tools and studies assigned a grade of "good," "fair," or "poor"; discrepancies were discussed and agreed upon by each author. We used the SEIPS model, which includes 5 work system components, to guide our analysis (Table 1), classifying each intervention based on the work system component(s) the studies intended to improve. Some interventions may be characterized as redesigning multiple work system components. Two authors (M. J. K., R. L. P. J.) separately reviewed each article, assigned interventions to each work system component, and then reached an agreement regarding assignments through discussion. While individualized education and feedback can be included under the work system component of "organization" in human factors methodology, we chose to analyze didactic educational interventions as a distinct factor rather than as a work system component.

RESULTS

The search strategy identified 86 potential studies. Subsequent screening of abstracts narrowed this to 11 potentially eligible studies. Examining the bibliographies of included studies, we found 9 additional studies that met our inclusion criteria. Five (25%) studies were randomized controlled trials, and the remaining 15 (75%) were quasi-experimental analyses (Tables 2 and 3).

Educational Interventions

Sixteen (80%) studies incorporated a structured educational element as part of their antimicrobial stewardship intervention, 14 of which included nurses. For 7 studies, the primary intervention was education, coupled with feedback, to prescribers and staff.

Pettersson et al [17] conducted a randomized controlled trial of 58 nursing homes in Sweden in which they applied a quality improvement framework to develop their educational material, holding focus groups with physicians, nurses, and nursing assistants. The intervention consisted primarily of education, including training on guidelines for treating infections common to nursing homes, as well as feedback about each nursing home's baseline characteristics. Although the primary outcome—the proportion of quinolones prescribed for urinary tract infections—did not change, the overall proportion of antibiotics prescribed decreased and the rate of adverse events did not increase. Schwartz et al, in a quasi-experimental study at a single hospital-based long-term care setting, compared local infection management practices to those of published guidelines in interactive sessions and also issued pocket guides [14]. They achieved a decrease in total antimicrobial use that was sustained for 2 years following the intervention.

Other studies provided individualized feedback to prescribers. Using a cluster randomized controlled trial involving 36 physicians from 8 nursing homes near Montreal, Monette et al mailed an antibiotic prescribing guide to all providers [15]. Those in the experimental group also received an individualized prescribing profile describing their recent antibiotic prescriptions as adherent or nonadherent to the guide. Compared to the control group, physicians in the experimental group were less likely to write nonadherent antibiotic prescriptions. Zimmerman et al introduced a comprehensive quality improvement program that involved training sessions for nursing staff

Table 2. Overview of Long-term Care Antibiotic Stewardship Interventions, Including the 5 Work System Components of the Systems Engineering Initiative for Patient Safety Model

Study, First Author [Ref]	Design (No. of Sites)	Quality Assessment	Structured Education	Nurses Included in Intervention	Work System Components					Measurable Change
					Tools and Technology	Tasks	Organization	Persons	Environment	
Naughton 2001 [11]	RCT (10)	Good	X	X	X		X		X	
Loeb 2005 [22]	RCT (24)	Good	X	X	X	X			X	X
Hutt 2006 [13]	QE (2)	Fair	X	X	X	X	X		X	
Schwartz 2007 [14]	QE (1)	Good	X	X	X					X
Monette 2007 [15]	RCT (10)	Fair	X		X					X
Zabarsky 2008 [16]	QE (1)	Good	X	X	X					X
Pettersson 2011 [17]	RCT (58)	Good	X	X						
Linnebur 2011 [18]	QE (16)	Fair	X	X	X			X		
Jump 2012 [19]	QE (1)	Good			X	X	X	X		X
Pate 2012 [20]	QE (1)	Good			X	X	X	X		X
Zimmerman 2014 [21]	RCT (12)	Fair	X	X	X					X
Fleet 2014 [22]	RCT (30)	Good	X	X	X	X			X	X
Benson 2014 [23]	QE (1)	Poor			X	X	X	X		X
Furuno 2014 [24]	QE (1)	Poor	X	X	X					
Van Buul 2015 [25]	QE (10)	Fair	X	X	X	X	X	X		
Trautner 2015 [26]	QE (2)	Good	X	X	X					X
Doernberg 2015 [27]	QE (3)	Fair				X	X	X		X
McMaughan 2016 [28]	QE (12)	Fair	X	X	X	X				X
Beaulac 2016 [29]	QE (1)	Good	X		X	X	X	X		X
Tedeschi 2016 [30]	QE (1)	Good	X	X	X	X	X	X		X

Abbreviations: QE, quasi-experimental; RCT, randomized controlled trial.

and, separately, providers at 6 nursing homes in North Carolina [21]. The study team developed pocket guides and medical care referral forms for the nursing staff. The latter document was seldom completed, though the nurses indicated they used the forms to support communication with prescribers. Nurses and prescribers received ongoing feedback about overall antibiotic prescribing rates and adherence to recommended guidelines. Compared to the 6 control facilities, the rate of antibiotic used in the intervention nursing homes decreased. A unique aspect of this study was the inclusion of residents and their families in quality improvement activities.

Two studies conducted at nursing homes in the Veterans Affairs (VA) Healthcare System, both of which focused on urinary tract infections, achieved outcomes that were sustained for at least 1 year following the intervention [16, 26]. The investigators instructed nursing home staff on appropriate indications for collecting urine cultures and communicated case-based recommendations to prescribers. These efforts reduced the number of urine cultures by 2-fold [16, 26]. Additionally, the work described by Zabarsky et al reduced total antibiotic use by 30% for 30 months following the intervention [16].

Naughton et al used a randomized controlled trial to compare the effect of multidisciplinary education vs physician-only education on adherence to antimicrobial prescription guidelines for nursing home-acquired pneumonia [11]. The multidisciplinary education arm, in which nursing staff and physicians attended different sessions, included prompting nurses to identify barriers and develop strategies to address them. Following the intervention, the percentage of prescriptions written in accordance with guidelines trended toward significance in the multidisciplinary group (82%) compared to the physician-only group (69%) ($P = .06$). These findings, however, should be interpreted with caution as the outcomes represented an increase in the proportion of parental vs oral antibiotics used, which is contrary to most antimicrobial stewardship goals.

Multimodal Interventions

While 7 studies intervened primarily through structured education, 13 other investigations incorporated 1 or more work system components. Figure 1 further details how the LTC antimicrobial stewardship interventions described fit into the work system components of the SEIPS model.

None of the studies reviewed here described a human factors systems approach as either an a priori or post hoc aspect of their intervention. Accordingly, as we analyzed the studies in the context of human factors, most interventions had aspects, beyond education, that crossed into 2 or more work system elements. Specifically, 4 of the interventions emphasized tools; 3 of them combined tools with tasks. The remaining 9 studies primarily involved redesign of the "organization" component of the work system, sometimes in conjunction with tools, persons, or technology. The studies that addressed the environment typically displayed posters or other educational materials near frequently used work areas to increase clinician exposure [11–13, 16, 22].

Table 3. Summary of Systems Engineering in Patient Safety (SEIPS) Analysis of Antimicrobial Stewardship Interventions in Long-term Care for Structured Education

Study, First Author [Ref]; Infectious Syndrome	Setting; Study Design	Structured Education		Work System Components					Outcomes
		Audience	Method	Tools and Technology	Tasks	Organization	Persons	Environment	
Naughton 2001 [11]; nursing home-acquired pneumonia	10 skilled nursing facilities; RCT	Nurses, prescribers[a]	Small group sessions, guidelines	Pocket guides		Nurses identified and implemented strategies to overcome barriers		Written materials posted in work areas	No difference in patient outcomes or adherence to guidelines
Loeb 2005 [31]; UTIs	24 nursing homes in Ontario and Idaho; RCT	Nurses, nurse assistants	Small group sessions, videotapes	Pocket guides with algorithm	Nurses completed form for suspected UTIs			Written materials posted in work areas	Reduced prescriptions for UTIs[d], no significant difference in total antibiotic usage
Hutt 2006 [13]; nursing home–acquired pneumonia	2 state veterans homes; pre/post comparison with comparator facility	Nurses, nurse assistants, prescribers	Small group sessions, feedback, guidelines, interactive discussions	Pocket guides, preprinted order sets	Vaccination	Guideline-recommended antibiotics available on-site		Written materials posted in work areas	No differences in adherence to guidelines for treatment or patient outcomes
Schwartz 2007 [14]	1 long-term acute care facility; quasi-experimental pre/post comparison	Nursing leadership, physicians	Small group sessions, feedback, guidelines, interactive discussions	Pocket guides					Reduction in total antimicrobial days[d] and increased adherence with guidelines for treatment[d]
Monette 2007 [15]	10 community nursing homes in Montreal; RCT	Physicians	Guideline, feedback (both mailed)	Prescribing guide (mailed)					Reduction in nonadherent antibiotic prescriptions after 2 interventions[d]
Zabarsky 2008 [16]; UTIs	1 VA nursing home; quasi-experimental pre/post comparison	Nurses, nurse assistants, physicians[a]	Small group sessions, feedback, guidelines	Pocket guides				Written materials posted in work areas	Reduced treatment of asymptomatic bacteriuria[d] and total antimicrobial days[d]
Pettersson 2011 [17]	58 nursing homes in Sweden; RCT	Nurses, nurse assistants, physicians	Small group sessions, feedback, guidelines, written materials						No difference in antimicrobial consumption or adherence to guidelines
Linnebur 2011 [18]; nursing home–acquired pneumonia	16 nursing homes in the US; quasi-experimental with comparator group	Nurses, nurse assistants, prescribers	Small group sessions, feedback, guidelines	Pocket guides, preprinted order sets	Promote use of guidelines and preprinted order sets		Nurse champion		No reduction in adherence to guidelines or patient outcomes
Jump 2012 [19]	1 VA nursing home; quasi-experimental pre/post comparison			Electronic medical record	Infectious disease consultation	Recommendations left in medical record; financial support for consultant	Infectious disease physician and nurse practitioner		Reduced total antimicrobial use and CDI rates[d]
Pate 2012 [20]	Long-term acute care hospital; quasi-experimental pre/post comparison			Paper form	Weekly chart review of patients on systemic antibiotics	Recommendations left in chart (not part of medical record)	Physician and pharmacist antimicrobial stewardship team		Reduced mean monthly cost of antibiotics[d] and mean total antimicrobial consumption[d]
Zimmerman 2014 [21]	12 US nursing homes; RCT	Nurses, nurse assistants, prescribers[a], residents and family members	Small group sessions, feedback, guidelines	Medical referral form; pocket guides					Reduction in total number of antibiotics prescribed[d]

Table 3. Continued

Study, First Author [Ref]; Infectious Syndrome	Setting; Study Design	Structured Education		Work System Components					Outcomes
		Audience	Method	Tools and Technology	Tasks	Organization	Persons	Environment	
Fleet 2014 [22]	30 nursing homes in London; RCT	Nurses, nursing leadership	Written materials	Paper form with tick boxes and free text	Nurses to complete form for newly prescribed antibiotics			Written materials posted in work areas	Reduced number of antibiotic doses[d], increased proportion of appropriate antibiotic prescribing[d]
Benson 2014 [23]	1 long-term acute care hospital; quasi-experimental pre/post comparison			Paper form to guide data collection	Daily chart review	Feedback to prescribers	Pharmacy students, pharmacists		Decrease in mean antibiotic cost[d]
Furuno 2014 [24]	1 skilled nursing home in Maryland; quasi-experimental pre/post comparison	Nurses, nursing leadership, physicians, administrators	Small group sessions	Antibiogram					No reduction in prevalence of appropriate antibiotic prescribing
Van Buul 2014 [25]	10 nursing homes in the Netherlands; quasi-experimental with comparator group	Nurses, physicians	Small group sessions, multidisciplinary meetings	Paper form	Physicians to complete form for suspected infection	Stakeholders at nursing homes decided on interventions to improve antibiotic prescribing	Research team helped nursing home choose interventions		No reduction in appropriate prescribing decisions or antimicrobial consumption
Trautner 2015 [26]; UTIs	2 Veterans Affairs nursing homes; pre/post comparison with comparator facility	Nurses, prescribers[a]	Small groups sessions, feedback, guidelines, algorithm	Guidelines (emailed)					Reduced treatment of asymptomatic bacteriuria[d]
Doernberg 2015 [27]; UTIs	3 nursing homes in California; quasi-experimental pre/post comparison				Weekly chart review	Feedback via telephone or fax	Infectious disease physician and pharmacist antimicrobial stewardship team		Decrease in antibiotic prescriptions for UTIs[d], no overall reduction in antibiotic prescriptions, CDI rates, or MDRO rates
McMaughan 2016 [28]; UTIs	12 nursing homes in Texas; pre/post comparison with comparator groups	Nurses	Training in tool with technical support	Paper form with tick boxes and free text	Nurses to complete form for newly prescribed antibiotics				Reduced prescriptions for asymptomatic bacteriuria[d]
Beaulac 2016 [29]	1 long-term acute care hospital; quasi-experimental pre/post comparison	Not specified	Small group sessions	Electronic medical record, email	Daily chart review	Recommendations made via email; financial support for consultants	ID physicians and pharmacists		Decrease in CDI cases[d], no significant decrease in total antimicrobial consumption
Tedeschi 2016 [30]	1 spinal-cord injury rehabilitation hospital in Italy; quasi-experimental pre/post comparison	Nurses, physicians	Small group sessions	Phone, email	ID consultation	Revision of protocols; financial support for consultant	ID physician		Decreased antibiotic consumption[d], mean length of stay of rehab patients[d], incidence of CDI[d], and rates of MDROs[d]

Abbreviations: CDI, *Clostridium difficile* infection; ID, infectious disease; MDRO, multidrug-resistant organism; RCT, randomized controlled trial; US, United States; UTI, urinary tract infection; VA, Veterans Affairs.

[a]For studies focused on a single type of infection.

[b]For sites that fit >1 category, the highest level of care/most common level of care was chosen.

[c]Includes physicians, nurse practitioners, and physician assistants.

[d]Indicates statistical significance ($P < .05$).

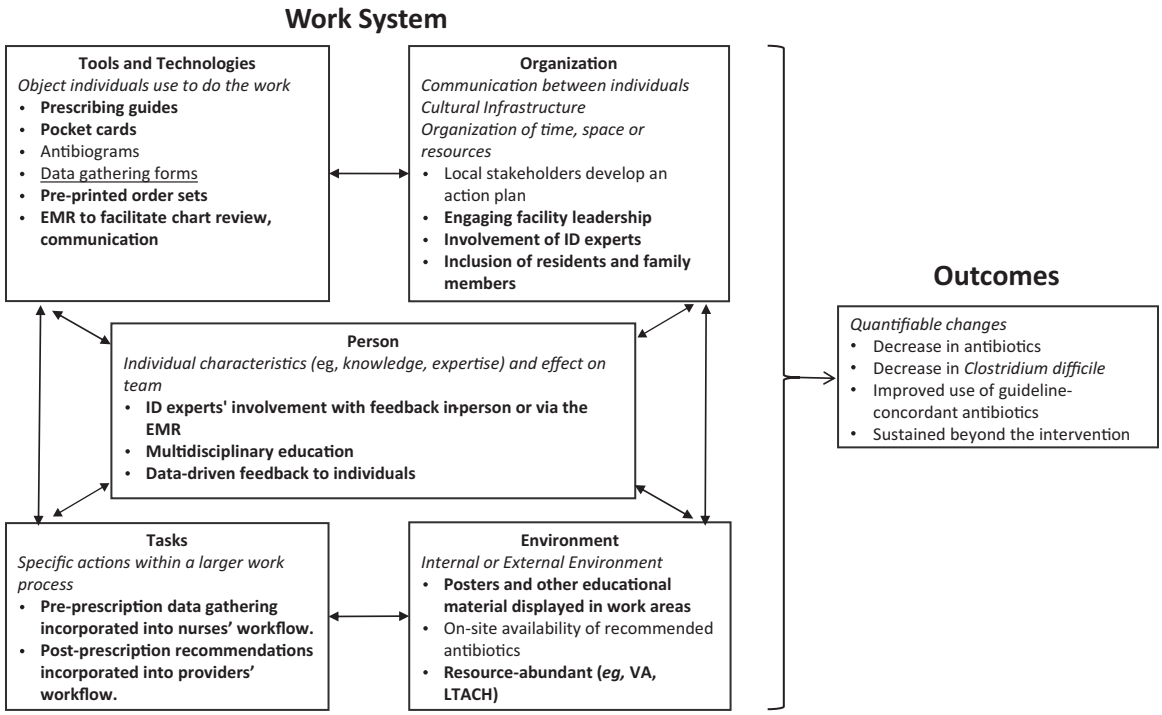

Figure 1. Adaptation of the work system from the Systems Engineering Initiative for Patient Safety (SEIPS) model to antimicrobial stewardship interventions in long-term care. Italicized text indicates the working definition used for each human factor. Bulleted text details specific interventions used in the studies reviewed here; bolded text indicates specific approaches that supported a quantifiable change in antibiotic use in accordance with principles of antibiotic stewardship. As detailed in the text, several of the interventions incorporated 2 or more human factors. Abbreviations: EMR, electronic medical record; ID, infectious disease; LTACH, long-term acute care hospital; VA, Veterans Affairs.

Hutt et al modified the environment by having guideline-recommended antibiotics available and accessible in each nursing home [13].

Several studies used tools, in the form of antibiotic prescribing guides and pocket cards, to support an educational intervention. Taking a distinct approach, Furuno et al incorporated nursing home-specific antibiograms as tools [24]. There was a modest increase in appropriate antibiotic prescribing from 32% to 45% in 1 of the 3 participating facilities, suggesting that as an isolated tool, antibiograms are not sufficient to support antimicrobial stewardship in LTCFs.

Three other studies incorporated tools along with tasks as part of their intervention. The interventions required nurses to complete written forms to support assessment of signs and symptoms of infection prior to the initiation of therapy [13, 22, 24]. Consisting mostly of checkboxes and short fill-in-the-blank answers, the research teams used the tools as part of multifaceted interventions. In addition to education, all 3 studies offered their participating facilities technical support related to their tool. The 2 studies that focused on urinary tract infection both achieved a decrease in antibiotics prescribed [28, 31]. The study by Fleet et al, for which the tool did not focus on a specific infection, also led to a reduction in total antibiotic consumption [22]. These outcomes suggest that incorporating tools into the pre-prescriptive tasks or workflow of nurses working in long-term care may be an effective means to support antimicrobial stewardship.

Nine of the studies employed an intervention that in some way modified the organization of the facility, such as changing communication strategies (review and feedback) or bolstering funding or stakeholder involvement; all of these supported changes in combination with 1–2 additional work system components. The most ambitious of these was a participatory action research approach characterized by the involvement of local stakeholders in the identification of opportunities for improved practice followed by the subsequent development, implementation, and evaluation of those changes [25]. Despite a well-executed study and tailored, multimodal interventions for 5 nursing homes in the Netherlands, the outcomes did not demonstrate improvement in appropriate antibiotic prescribing. This is discordant with other quality improvement studies in healthcare citing the importance of leadership engagement [32]. Qualitative interviews with local stakeholders in the study attributed the modest results to high physician turnover and time restrictions.

Focusing on nursing home–acquired pneumonia, 2 studies launched interventions affecting the organization, supported with tools in the form of preprinted order sets and pocket guides [13, 18]. Hutt et al initiated their study with a formative phase that engaged facility leadership [13]. Their intervention involved order sets and procedures at the institutional level and

tailored education at the nursing and physician level. Linnebur et al expanded upon this approach by engaging the prescribers through academic detailing. Both interventions improved the selection and timing of guideline-adherent antibiotic prescribed for nursing home-acquired pneumonia, suggesting that a more targeted plan for organizational involvement, perhaps in conjunction with education and tools, may favor improved appropriateness of antimicrobial use [18].

Three studies, none of which incorporated a structured educational component, invoked the work system components of organization and persons by having individuals with specific expertise influence communication and work processes. Working with an LTACH, Pate et al describe an intervention led by a pharmacist and infectious disease physician who drafted a stewardship policy for the facility and conducted weekly chart reviews [20]. The team communicated recommendations for changes in antibiotics through written notes left in the chart but did not become part of the medical record. With 80% of the recommendations accepted, their efforts resulted in a 21% reduction in mean monthly antimicrobial use (P = .003) and an estimated cost savings from pharmaceutical purchases of $159 580. Benson reported a similar intervention at an LTACH in which supervised pharmacy students reviewed antibiotic prescriptions and provided feedback to prescribers daily, with an estimated $261 630 in cost savings [23]. The third study took place in 3 community nursing homes [27]. An antimicrobial stewardship team performed weekly audit and feedback of prescriptions written for urinary tract infections. Of the 40 prescriptions for which the team recommended changes, only 10% were implemented. Together, these findings may suggest that compared to nursing homes, providers working at LTACHs may be more accepting of organizational changes or of the persons recommending those changes.

Recently, Tedeschi et al described an antimicrobial stewardship program at a spinal cord rehabilitation hospital in Italy that focused on redesigning the work components of organization and persons as well as structured education [30]. The outcomes, measured over a 30-month period, included an approximately 50% decrease in total antibiotic consumption (P < .001), a decrease in the incidence of *Clostridium difficile* infections from 3.6 to 1.2 cases per 10 000 PD (P = .001) and a decrease in the prevalence of several different multidrug-resistant organisms.

Finally, 2 studies used the work system components of organization and persons combined with technology in the form of an electronic medical record. Interestingly, both of these occurred in relatively resource-abundant settings. Jump et al implemented an on-site consultation service at a VA nursing home consisting of weekly rounds by an infectious disease physician and nurse practitioner [19]. The consult team communicated their recommendations in the electronic medical record and, when feasible, in face-to-face or telephone conversations with nursing home providers. This intervention led to a 30% reduction in total antimicrobial use, increased use of narrow-spectrum agents and decreased the rate of positive *C. difficile* tests. For a Massachusetts LTACH, Beaulac et al used telemedicine to perform antimicrobial stewardship via remote electronic medical record access [29]. Overall, LTACH providers accepted about 50% of the antimicrobial stewardship recommendations within 72 hours, leading to a significant decrease in both antibiotic usage and monthly hospital-acquired cases of *C. difficile* infection [29].

Together, the 6 interventions that involved the work systems components of organization and persons appear to offer the most consistent and effective antimicrobial stewardship outcomes in LTCFs.

DISCUSSION

Our integrative review used a human factors engineering approach as a framework to analyze the literature describing antimicrobial stewardship interventions in LTCFs. By considering each study within the context of both educational efforts and work system components, we identified the following approaches as effective, and potentially complementary, strategies to support antimicrobial stewardship in LTCFs: multidisciplinary education supported by enduring material; integrating pre-prescriptive data collection tools into nurses' workflow; integrating post-prescriptive recommendations into prescribers' workflow; and employing external consultants with expertise in infectious diseases.

Structured education that engages nurses, nurse assistants, and prescribers may represent a feasible, pragmatic, and cost-effective strategy for LTCFs, particularly when bolstered by comprehensive approaches, such as incorporating actionable items into pocket guides and posting educational materials in common areas. While education alone may be an effective intervention to initiate antimicrobial stewardship [14, 16, 17, 26], behavior change theory suggests this will not result in sustained practice changes by healthcare workers [19, 29, 33]. The sustained antimicrobial stewardship effects achieved by Zabarsky et al and Trautner et al [16, 26]. both occurred at VA nursing homes, which may have influenced the outcomes through a relative abundance of resources and longer tenure of personnel [34, 35]. Training several levels of staff, all of which seem to have an effect on the prescribing process, also appears to be important. Zabarsky et al attributed the positive outcomes of their intervention to involvement of the nursing staff to reduce the number of urine cultures sent for asymptomatic bacteriuria. Qualitative studies emphasize a substantial reliance on nursing staff for care decisions in LTCF [36] and indicate that nurse education and training may enhance nurses' participation in antimicrobial stewardship [37]. In contrast to nursing homes with a hierarchical culture, facilities that support communication among persons in different roles appear to have lower

rates of antibiotic use [38]. Together, these findings suggest that future interventions might attempt simultaneous education of nurses, nurse assistants, and providers, which may foster multidisciplinary communication.

Tools may augment multidisciplinary education. Those used by studies described above [12, 22, 28], as well as similar tools described elsewhere [39–42], all serve to improve gathering relevant clinical information and enhancing communication among prescribers and nurses. Integration of these tools into nurses' workflow at a pre-prescriptive stage has the potential to lead to sustainable improvements in antimicrobial prescriptions with occasional technical or implementation support from individuals outside of day-to-day nursing home operations [31]. Ideally, as electronic medical records become the norm, tools and technology supportive of antimicrobial stewardship practices will be embedded in to these systems.

External consultants with infectious disease expertise, representing the work system components of organization and persons, proved to be effective in resource-abundant settings. Communication through medical charts, electronic medical records, or emails, representing tasks that may be accessed at the prescriber's convenience and therefore may fit into their workflow, may have fostered acceptance of changes in antibiotic orders. Communication to providers by fax or telephone, representing tasks that may be received at a time or location not conducive to changing antibiotic orders or chart review, could have been a factor in the marginal success reported by Doernberg et al [27]. Telemedicine may improve the financial feasibility and scalability of using external consultants to promote antimicrobial stewardship for long-term care settings. Although only 1 intervention focused on involvement of local stakeholders and reported modest results [25], the regulatory changes from CMS will likely engender leadership commitment that will promote effective antimicrobial stewardship programs in LTCFs [2, 34].

Supplementary Data

Supplementary materials are available at *Clinical Infectious Diseases* online. Consisting of data provided by the authors to benefit the reader, the posted materials are not copyedited and are the sole responsibility of the authors, so questions or comments should be addressed to the corresponding author.

Notes

Disclaimer. The findings and conclusions in this document are those of the authors, who are responsible for its content, and do not necessarily represent the views of the Agency for Healthcare Research and Quality (AHRQ), National Institutes of Health (NIH), or Department of Veterans Affairs. No statement in this report should be construed as an official position of the AHRQ or of the US Department of Health and Human Services.

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