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Changing the antibiotic prescribing of Australian general practice registrars' for acute respiratory tract infections: a non-randomized controlled trial

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Abstract

Background: Inappropriate antibiotic prescription for self-limiting respiratory tract infections (RTIs) by general practitioner (GP) registrars (trainees) is less common than by established GPs but still exceeds evidence-based benchmarks. A 2014 face-to-face educational intervention for registrars and supervisors reduced registrars' acute bronchitis antibiotic prescription by 16% (absolute reduction). We aimed to establish the efficacy of an updated registrar/supervisor RTI-management intervention (delivered at distance) on antibiotic prescribing.

Methods: A non-randomized trial using a non-equivalent control-group nested within the ReCEnT cohort study. The intervention included online educational modules, registrar and supervisor webinars, and materials for registrar-supervisor in-practice educational sessions, and focussed on acute bronchitis as an exemplar RTI. The theoretical underpinning was the 'capability, opportunity, and motivation' (COM-B) framework. The intervention was delivered to registrars and supervisors of one large educational/training organization annually from mid-2021, with pre-intervention period from 2017, and with postintervention period ending 2023. Two other educational/training organizations served as controls. The primary outcome was antibiotics prescribed for acute bronchitis. Analyses used multivariable logistic regression with predictors of interest: time (before/after intervention), treatment group, and an interaction term for time-by-treatment group, adjusted for potential confounders. The interaction term *P*-value was used to infer statistical significance of the intervention effect.

Results: Of 4612 acute bronchitis presentations, 70% were prescribed antibiotics. There was a 6.9% absolute reduction (adjusted) of prescribing in the intervention-group compared with the control-group. This was not statistically significant ($P_{\text{interaction}} = .22$).

Conclusions: Failure to find a significant effect on prescribing suggests difficulties with scalability of this (and similar educational) innovations.

Keywords: anti-bacterial agents; general practitioners; respiratory tract infections; graduate medical education; antimicrobial stewardship; non-randomized controlled trials

Introduction

Antimicrobial resistance is a global health concern with over 1 million deaths estimated as attributable to bacterial resistance in 2019 [1]. Antibiotic overprescribing is a key contributor to antibiotic resistance and much of this prescribing occurs in primary care [2, 3]. In Australia, a large proportion of antibiotic overprescribing occurs for non-pneumonia acute respiratory tract infections (ARTIs), of which acute bronchitis is an important component [3].

Evidence-based guidelines consistently recommend against prescribing antibiotics for acute bronchitis [4] as there is evidence of minimal, if any, clinical benefit [5]. Despite this, Australian general practitioners (GPs) prescribed antibiotics in 81% of acute bronchitis cases in 2021 [3]. Prescribing rates for other ARTIs [upper RTI (antibiotics not recommended) and acute otitis media, acute sore throat, and acute sinusitis [antibiotics recommended in only a minority of cases]) are similarly in excess of Australian [6] and international benchmarks [7, 8]. This evidence highlights a need to reduce antibiotic prescribing for ARTIs in the primary care setting.

Antimicrobial stewardship programs are effective in reducing antibiotic prescribing [9]. In recent years, several educational interventions have been shown to effectively reduce

Key messages

- An online educational intervention for GP trainees aimed to reduce antibiotic prescribing.
- Antibiotic prescribing for acute bronchitis reduced by a statistically non-significant 6.9%.
- With no statistically significant prescribing reductions for other respiratory infections.
- Wholly online delivery mode may be inferior to face-to-face for antibiotic stewardship.

inappropriate antibiotic prescribing for ARTIs in primary care [10–14].

GP vocational trainees (in Australia, 'registrars') are an important target group for educational interventions, as they are establishing practice patterns and there is evidence to suggest that a GP's clinical practice behaviours (including antibiotic prescribing habits) remain stable over time [15, 16]. Registrars currently prescribe antibiotics at a lower rate than established GPs (~72% of new acute bronchitis cases receive an antibiotic prescription from registrars [17] compared with 81% in established GPs [3]). However, this rate is still well above national benchmarks which suggest not prescribing antibiotics in acute, uncomplicated bronchitis [6].

We have previously developed a multi-modal educational program informed by a behavioural change theoretical approach (the 'capability, opportunity, and motivation' COM-B system) [18] targeting antibiotic stewardship in GP registrars. Our initial 2014 study found that this educational intervention reduced antibiotic prescribing for bronchitis by 16% (absolute reduction [19, 20]). This intervention was delivered via an educational package that included face-to-face sessions with registrars and, separately, with their clinical supervisors [19]. These face-to-face components presented challenges for the scalability of the educational package. The aim of the current study was to assess the efficacy of a scalable, online-delivered, updated version of the previous educational intervention. That is to assess the efficacy of a multi-modal online-delivered antimicrobial stewardship program in (the primary outcome) increasing registrars' adherence to evidence-based guidelines for antibiotics for acute bronchitis (i.e. reducing prescribing). We also aimed to assess any 'ripple out' effect of the intervention in reducing antibiotic prescribing for other ARTIs.

Materials and Methods

Study design

This study was a pragmatic, non-randomized, controlled trial employing a non-equivalent control group design, nested within the Registrar Clinical Encounters in Training (ReCEnT) ongoing inception cohort study.

Setting and participants

Participants were GP registrars from three of Australia's nine Regional Training Organizations (RTOs). These three RTOs were responsible for training 44% of Australian registrars [21]. RTOs were government-funded, not-for-profit, geographically defined training organizations. For our study participants, from 2023, RTOs' functions were assumed by the Royal Australian College of General Practitioners (RACGP), but geographically defined training regions were retained for the purposes of this study.

In Australia, GP registrars undertake three mandatory terms in general practice under the supervision of an established GP. Each term is 6-month full-time-equivalent. While they have access to advice and assistance from their supervisor, registrars practice independently and have equivalent prescribing rights to established GPs.

GP registrars also receive out-of-practice educational sessions from their regional training provider (RTO/RACGP) to complement their within-practice experiential learning. Of the RTOs participating in this study, the intervention RTO trained registrars in New South Wales and the Australian Capital Territory (NSW and ACT). The second and third (control) RTOs trained registrars in Eastern Victora (EV) and Tasmania (Tas).

ReCEnT

ReCEnT is an ongoing inception cohort study of GP registrars in each of their three mandatory 6-month community-based training terms. This study documents registrars' in-consultation clinical and educational experiences, including prescribing habits. The methodology has been published previously [22].

Each term, registrars complete a questionnaire documenting their own and their training practice's, demographic details. Registrars then record details of 60 consecutive consultations via an individually accessed online portal. Only office-based consultations (not home or aged care facility visits) are recorded. Recorded data include patient and consultation factors. Consultation factors included the problems/diagnoses [coded using the International Classification of Primary Care, 2nd edition-Plus (ICPC2+) system] [23] and any medication linked to those diagnoses [coded using the Anatomic Therapeutic Chemical (ATC) Classification system] [24].

ReCEnT is an integral part of registrars' education and training, being the basis for feedback and reflection on practice [25]. In addition, registrars have the option to consent to their data being used for research purposes.

Study population

Registrars in Terms 1, 2, and 3 of their vocational training program at three RTOs between first semester 2017 and second semester 2023.

Ethics approval

Ethics approval was provided by the Human Research Ethics Committee of the University of Newcastle: H-2009-0323 (2009-2023) and the Royal Australian College of General Practitioners National Research and Evaluation Ethics Committee: NREEC-23-0000000161 (2023-present).

Intervention group

The antimicrobial stewardship intervention was delivered to intervention region registrars (registrars training in the NSW and ACT RTO) and their supervisors in 2021, 2022, and 2023.

The main components of the intervention were an online learning module [11, 26], an interactive webinar led by an expert panel and informed by the literature [4, 17, 27–33], and a shared registrar/supervisor activity (See Supplementary Table 1). Intervention materials were updated yearly to incorporate emerging evidence and comprised:

Registrar components
(1) Required reading of two online learning modules
(2) An online webinar with opportunity for audience interaction
(3) Detailed written responses to registrar questions arising from the webinar

Supervisor components
(4) Access to the two online learning modules
(5) An online webinar with opportunity for audience interaction (first year of delivery – subsequently, access to recording of the original webinar)
Joint activities
(6) Frameworks for case-based education sessions for the GP registrar and their supervisor (to be conducted during structured in-practice teaching time)

Components 1 and 2 were mandatory parts of registrars' education programs. Components 3–6 were discretionary. See

Table 1. List of covariates entered in multivariable analyses.

Category	Variable	Class	Details
Patient	Patient age group	Varies	Patient age groupings vary depending on diagnoses
	Patient gender	Male Female	N/A
	Aboriginal and/or Torres Strait Islander	No Yes	The patient's Aboriginal and/or Torres Strait Islander status
	Patient/practice status	Existing patient New to registrar New to practice	Whether the patient was new to the registrar, new to the practice, or a returning patient
Registrar	Registrar age	mean (SD)	Reported as years
	Registrar gender	Male Female	N/A
	Registrar workload	Part-time Full-time	Whether the registrar is training part-time (less than 0.8 full time equivalent) or full-time hours
	Training term	Term 1 Term 2 Term 3	Which training term was the registrar in at the time of the consultation
	Worked at practice previously	No Yes	Has the registrar worked in the current practice previously during their training
	Qualified as doctor in Australia	No Yes	Refers to the source of primary medical degree (qualified as a doctor in Australia, or internationally).
Practice	Practice size	Small Large	Number of GPs at practice "Small" = 1–4 GPs, "Large" = 5+ GPs
	Practice routinely bulk bills	No Yes	Bulk billing refers to whether the practice routinely requires no patient contribution to the cost of the consultation
	Rurality	Major city Inner regional Outer regional /remote	Measure of rurality of the practice location. Remoteness classification from the Australian Government Department of Health and Aged Care. Australian Statistical Geographical Classification—Remoteness Area. https://www.health.gov.au/health-topics/rural-health-workforce/classifications/asgs-ra
	Socio-Economic Indexes for Areas—Index of Relative Socio-Economic Disadvantage (SEIFA-IRSD)	mean (SD)	Measure of socioeconomic status of the practice location. Decile of the practice location from the Australian Bureau of Statistics. https://www.abs.gov.au/websitedbs/censushome.nsf/home/seifa)
Consultation	Consultation duration	mean (SD)	Reported as minutes
	Pathology ordered	No Yes	Pathology was ordered for that problem/diagnosis
	Imaging ordered	No Yes	Imaging was ordered for that problem/diagnosis
	Follow-up ordered	None With themselves Other GP in the practice	Whether the registrar scheduled a follow-up consultation with themselves or another GP in the practice
	Number of diagnoses	mean (SD)	The number of individual problems/diagnoses addressed per consultation

Supplementary Table 1 for detailed description of intervention components.

Control group

The control group (registrars training in the EV RTO and Tas RTO) received ‘usual education’ as was delivered within the individual RTO during the study period. This included usual education relating to the management of ARTIs and antibiotic stewardship, but not the focussed, integrated program produced for our intervention. See Supplementary Fig. 1 for details regarding the non-equivalent control groups design.

Outcome factor

The outcome was the prescription of systemic antibiotics. ATC codes classified as systemic antibiotics for these analyses can be found in Supplementary Table 2.

Independent variables

A broad range of potential confounding variables (relating to patients, registrar, practice, and consultation factors) were considered for inclusion in analyses (see Table 1).

Statistical analyses

Analyses were performed on an intention-to-treat basis (i.e. including all registrars who were eligible to receive the educational intervention). The pre-intervention group included all registrars’ data from 1st Semester 2017 to 1st Semester 2021. The postintervention group included registrars in the intervention RTO/region who had been eligible to receive the intervention, and the equivalent control registrars, from 2nd Semester 2021 to 2nd Semester 2023. See Supplementary Fig. 2 for details of included/excluded registrars. Our study design (Supplementary Fig. 1) and the scheduling of our educational intervention and ReCEnT data collection meant the postintervention data did not include any Term 1 registrars. To evaluate this impact of the exclusion of Term 1 registrars from postintervention data, we also completed a sensitivity analysis (for the primary analysis) where Term 1 registrars were excluded from all pre-intervention data.

The primary analysis was of antibiotic prescribing for new diagnoses of acute bronchitis/bronchiolitis (ICPC2-PLUS code R78). Hereafter referred to as ‘bronchitis’.

Secondary analyses were of antibiotic prescribing for new diagnoses of URTI; acute sore throat; acute otitis media; acute sinusitis; and all ARTIs (combined), respectively. See Supplementary Table 3 for the ICPC-PLUS codes.

Descriptive statistics included frequencies for categorical variables and mean with SD for continuous variables.

Univariable and multivariable logistic regression has been used within the generalized estimating equations framework to account for repeated measures within registrars. An exchangeable working correlation structure was assumed.

All multivariable regressions included an interaction term between Time [or Time (sensitivity)] and Treatment Group. The interaction approach is a statistical method used to account for differing baseline measures in a non-randomized trial [1]. The interaction term *P*-value was used to infer a statistical significance of the intervention.

Table 2. Registrar and practice characteristics, at registrar-round level, by control vs intervention groups and pre-intervention vs postintervention groups.

Characteristic	Subgroup or mean (SD)	Control vs intervention demographics (*n* (%))			Pre- vs postintervention (*n* (%))		
		Control (*n* = 2208)	Intervention (*n* = 5660)	*P*	Pre-(*n* = 5973)	Post-(*n* = 1895)	*P*
Registrars							
Registrar gender	Male	977 (44.5)	2310 (41.1)	.01	2457 (41.3)	830 (44.4)	.02
	Female	1217 (55.5)	3316 (58.9)		3494 (58.7)	1039 (55.6)	
Qualified as a doctor in Australia	No	298 (13.6)	1153 (20.7)	<.001	1095 (18.6)	356 (18.8)	.86
	Yes	1894 (86.4)	4419 (79.3)		4778 (81.4)	1535 (81.2)	
Registrar workload	Part-time	478 (21.9)	1173 (22.2)	.78	1310 (23.6)	341 (18.0)	<.001
	Full-time	1701 (78.1)	4104 (77.8)		4253 (76.5)	1552 (82.0)	
Training term	Term 1	638 (28.9)	1719 (30.4)	<.001	2357 (39.5)	0 (0)	<.001
	Term 2	766 (34.7)	2208 (39.0)		1896 (31.7)	1078 (56.9)	
	Term 3	804 (36.4)	1733 (30.6)		1720 (28.8)	817 (43.1)	
Registrar age (years)	mean (SD)	31.9 (5.3)	33.0 (6.3)	<.001	32.7 (6.2)	32.7 (5.7)	.57
Practices							
Rurality	Major city	1272 (57.6)	3474 (61.4)	.01	3673 (61.5)	1073 (56.7)	<.001
	Inner regional	786 (35.6)	1847 (32.6)		1903 (31.9)	730 (38.5)	
	Outer regional /remote	149 (6.8)	338 (6.0)		396 (6.6)	91 (4.8)	
Practice routinely bulk bills	No	1665 (76.1)	3133 (58.9)	<.001	3439 (61.3)	1359 (71.7)	<.001
	Yes	524 (23.9)	2186 (41.1)		2174 (38.7)	536 (28.3)	
Practice size	Small	632 (29.1)	2443 (46.3)	<.001	2347 (42.2)	728 (38.5)	.01
	Large	1540 (70.9)	2837 (53.7)		3215 (57.8)	1162 (61.5)	
SEIFA-IRSD decile	median (min, max)	6 (1, 10)	5 (1, 10)	<.001	5 (1, 10)	5 (1, 10)	.001
	mean (SD)	5.6 (2.8)	5.2 (2.8)		5.2 (2.8)	5.5 (2.8)	

An augmented backward selection process was followed to select explanatory variables for inclusion in the final multivariable model for each outcome. Variables in the model with *P*-values > .2 were tested for removal. A variable was removed if the resulting model did not have substantively different effect sizes than the previous model. A substantively different effect size (beta coefficient) was defined as being more than about 10% different to its value in the previous model.

Model fit was assessed using the Hosmer–Lemeshow goodness of fit (H-L) test. The logistic model assumption of linearity in the log-odds for continuous variables was also checked.

Table 3. Characteristics associated with antibiotic prescribing for acute bronchitis

			Antibiotics prescribed		
Variable group	**Variable**	**Class**	**No**	**Yes**	***P***
Study	Treatment	Control	357 (29%)	949 (33%)	.06
		Intervention	877 (71%)	1889 (67%)	
Time	Time	Postintervention	250 (20%)	471 (17%)	.02
		Pre-intervention	984 (80%)	2367 (83%)	
Patient	Patient age group	0–4	507 (41%)	332 (12%)	<.001
		5–14	68 (6%)	184 (7%)	
		15–24	89 (7%)	252 (9%)	
		25–44	215 (18%)	654 (23%)	
		45–64	206 (17%)	756 (27%)	
		65+	142 (12%)	629 (22%)	
	Patient gender	Male	584 (48%)	1235 (44%)	.02
		Female	630 (52%)	1564 (56%)	
	Aboriginal and Torres Strait Islander status	No	1056 (97%)	2482 (97%)	.20
		Yes	35 (3%)	66 (3%)	
	Patient/practice status	Existing patient	371 (31%)	743 (27%)	.07
		New to registrar	735 (61%)	1769 (64%)	
		New to practice	108 (9%)	271 (10%)	
Registrar	Registrar age	mean (SD)	32.57 (5.80)	33.10 (6.45)	.02
	Registrar gender	Male	564 (46%)	1282 (45%)	.86
		Female	663 (54%)	1541 (55%)	
	Registrar workload	Part-time	273 (23%)	611 (23%)	.80
		Full-time	911 (77%)	2081 (77%)	
	Training term	Term 1	381 (31%)	821 (29%)	.21
		Term 2	464 (38%)	1141 (40%)	
		Term 3	389 (32%)	876 (31%)	
	Worked at practice previously	No	891 (75%)	1990 (74%)	.27
		Yes	298 (25%)	717 (26%)	
	Qualified as doctor in Australia	No	241 (20%)	631 (23%)	.02
		Yes	976 (80%)	2168 (77%)	
Practice	Practice size	Small	498 (42%)	1074 (40%)	.22
		Large	686 (58%)	1632 (60%)	
	Practice routinely bulk bills	No	811 (68%)	1782 (65%)	.08
		Yes	384 (32%)	956 (35%)	
	Rurality	Major city	761 (62%)	1692 (60%)	.61
		Inner regional	393 (32%)	959 (34%)	
		Outer regional remote	80 (6%)	187 (7%)	
	SEIFA-IRSD decile	mean (SD)	5.57 (2.75)	5.56 (2.78)	.99
Consultation	Consultation duration	mean (SD)	18.73 (8.79)	17.31 (7.87)	<.001
	Imaging ordered	No	1144 (93%)	2463 (87%)	<.001
		Yes	90 (7%)	375 (13%)	
	Follow-up ordered	None	660 (53%)	1323 (47%)	.001
		With themselves	529 (43%)	1389 (49%)	
		Other GP in the practice	45 (4%)	126 (4%)	
	Number of diagnoses	mean (SD)	1.41 (0.69)	1.43 (0.71)	.31

Significance was declared at the conventional 0.05 level for all regressions, with the magnitude and precision of effect estimates also used to interpret results. Analyses were programmed using STATA 18.0 and SAS V9.4.

Results

This study included data from 3431 individual registrars, contributing 7868 registrar-rounds of data and a total of 42 214 new ARTI diagnoses.

There were 2208 registrar-rounds of data in the control group and 5660 registrar-rounds in the intervention group. There were 5973 registrar-rounds of pre-intervention data and 1895 registrar-rounds of postintervention data. The response rate for registrars participating during the study period was 93.6%. See Table 2 for full registrar and practice characteristics.

Primary outcome: antibiotic prescription rates for acute bronchitis

There were 3351 diagnoses of acute bronchitis pre-intervention and 721 postintervention. Overall, 69.7% of acute bronchitis diagnoses were treated with antibiotics. See Supplementary Fig. 1 for total numbers of acute bronchitis diagnoses in each treatment group.

Characteristics associated with antibiotic prescribing for acute bronchitis, including the numbers and percentages of patients who received antibiotics for acute bronchitis, by treatment and time, can be found in Table 3. The proportions of antibiotics prescribed for bronchitis by registrars in the control group compared with the intervention group over time are displayed in Fig. 1. Pre-intervention, 72.4% of the control and 69.8% of the intervention group bronchitis presentations were treated with antibiotics.

Postintervention, prescribing in the control group increased by 2.1%. Prescribing in the intervention group decreased by 7.8% (Fig. 1A). After adjustment for confounding (see variables in Table 1), the proportions of bronchitis consultations for which antibiotics were prescribed reduced by 0.6% in the control group and by 7.5% in the intervention group (representing an absolute reduction of 6.9% in the intervention group compared with the control group, Fig. 1B). This difference was not statistically significant ($P_{\text{interaction}}$ = .2)—see Table 4 for the univariable and multivariable logistic regression models for outcome prescribing antibiotics for acute bronchitis. The H-L *P*-value (*P* = .54) indicated satisfactory model fit. The C-statistics of 0.72 indicated moderate predictive accuracy. There did not appear to be any violations of linearity in the log-odds for the continuous variables.

Findings of the sensitivity analysis (removing 1st semester registrars from the pre-intervention group) were similar ($P_{\text{interaction}}$ = .5; see Supplementary Tables 4 and 5).

Secondary outcomes: antibiotic prescription rates for non-bronchitis ARTIs

The percentages of diagnoses for which antibiotics were prescribed for new cases of URTI, sinusitis, sore throat, otitis media, and all ARTI diagnoses are presented in Supplementary Tables 6–10, respectively. These figures are grouped by control versus intervention groups and by postintervention versus pre-intervention groups. Supplementary Tables 5–9 also include details on the characteristics associated with antibiotic prescribing for these five respiratory infection categories.

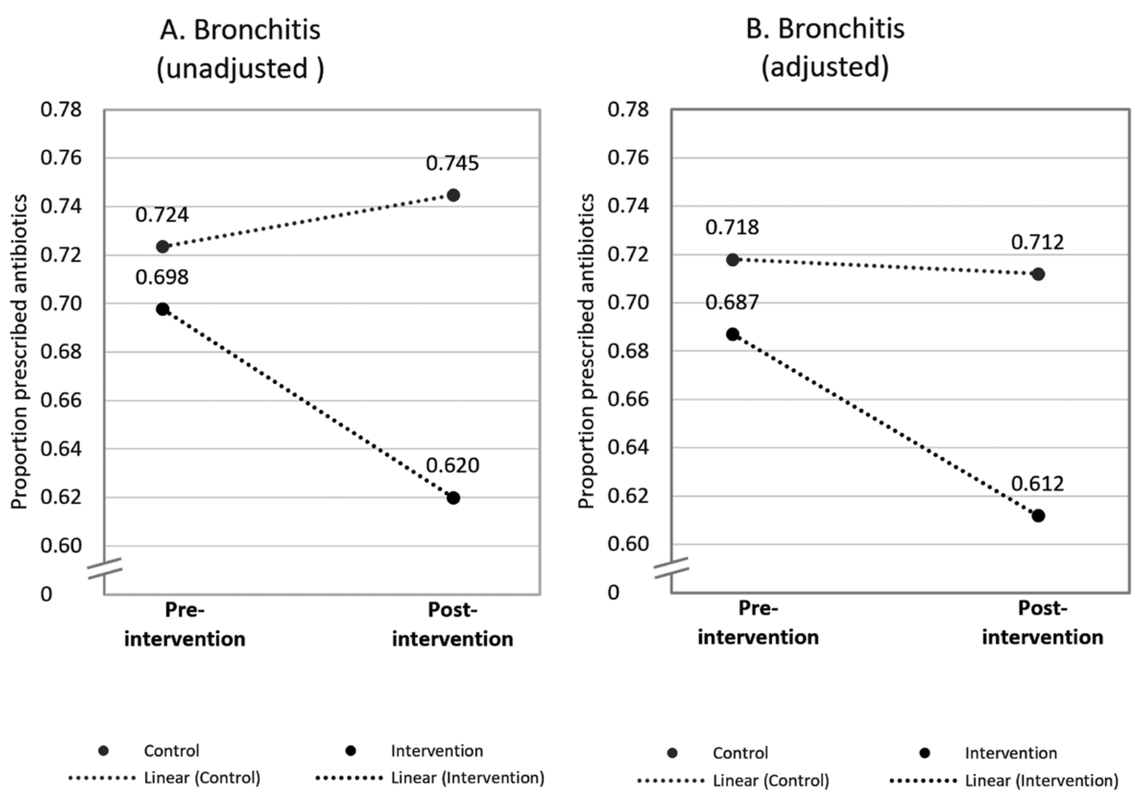

Figure 1. Unadjusted (A) and adjusted (B) proportions of antibiotics prescribed for acute bronchitis by intervention over time (main analysis).

Table 4. Study, time, patient, registrar, practice, and consultation variables associated with antibiotic prescribing for bronchitis

			Univariable		Adjusted	
Variable group	Variable	Class	OR [95% CI]	*P*	OR [95% CI]	*P*
Study	Treatment	Intervention	0.85 (0.72, 1.01)	.06	0.84 (0.67, 1.06)	.14
Time	Time	Postintervention	0.79 (0.65, 0.97)	.02	0.97 (0.59, 1.58)	.90
Interaction	***Interaction***	***Treatment group and Time***	N/A		***0.70 (0.40, 1.24)***	***.22***
Patient	Patient age group	0–4 (referent)	1.00	-	1.00	-
		15–24	4.37 (3.34, 5.71)	<.001	4.45 (3.21, 6.17)	<.001
		25–44	4.80 (3.89, 5.91)	<.001	4.96 (3.84, 6.40)	<.001
		45–64	5.70 (4.65, 6.99)	<.001	6.16 (4.78, 7.95)	<.001
		5–14	4.22 (3.15, 5.65)	<.001	5.24 (3.64, 7.56)	<.001
		65+	6.70 (5.40, 8.33)	<.001	7.30 (5.54, 9.61)	<.001
	Patient gender	Female	1.17 (1.03, 1.33)	.02	0.97 (0.82, 1.14)	.68
	Aboriginal and Torres Strait Islander status	Yes	0.77 (0.51, 1.15)	.20	1.01 (0.63, 1.61)	.97
		Existing patient (referent)	1.00	-	1.00	-
	Patient/practice status	New to registrar	1.18 (1.02, 1.37)	.03	1.19 (0.98, 1.45)	.08
		New to practice	1.20 (0.94, 1.53)	.15	1.39 (1.02, 1.89)	.03
Registrar	Registrar age		1.02 (1.00, 1.03)	.02	1.01 (0.99, 1.03)	.19
	Registrar gender	Female	1.01 (0.87, 1.19)	.86	1.07 (0.88, 1.31)	.50
	Registrar workload	Part-time	0.98 (0.82, 1.17)	.80	0.93 (0.74, 1.16)	.52
		Term 1 (referent)	1.00	-	1.00	-
	Training term	Term 2	1.16 (0.98, 1.36)	.08	1.12 (0.88, 1.43)	.36
		Term 3	1.06 (0.90, 1.26)	.48	0.96 (0.75, 1.23)	.75
	Worked at practice previously	Yes	1.09 (0.93, 1.28)	.28	1.22 (0.95, 1.55)	.12
	Qualified as doctor in Australia	Yes	0.80 (0.65, 0.97)	.02	0.83 (0.62, 1.11)	.20
Practice	Practice size	Small	0.91 (0.78, 1.06)	.22	0.91 (0.75, 1.10)	.32
	Practice routinely bulk bills	Yes	1.15 (0.98, 1.36)	.08	1.30 (1.04, 1.63)	.02
		Major cities (referent)	1.00	-	1.00	-
	Rurality	Inner regional	1.09 (0.92, 1.28)	.33	0.93 (0.72, 1.20)	.55
		Outer regional remote	1.07 (0.79, 1.45)	.67	0.78 (0.51, 1.18)	.23
	SEIFA-IRSD decile		1.00 (0.97, 1.03)	.98	1.01 (0.97, 1.05)	.50
Consultation	Consultation duration		0.98 (0.97, 0.99)	<.001	0.98 (0.97, 0.99)	.003
	Imaging ordered	Yes	1.94 (1.52, 2.48)	<.001	1.44 (1.04, 1.99)	.03
		None (referent)	1.00	-	1.00	-
	Follow-up ordered	Other GP in the practice	1.34 (0.96, 1.87)	.08	1.36 (0.91, 2.06)	.14
		With themselves	1.28 (1.11, 1.47)	.001	1.44 (1.20, 1.72)	<.001
	Number of diagnoses		1.05 (0.96, 1.16)	.31	0.95 (0.84, 1.07)	.37

There were no significant differences in antibiotic prescribing for URTI ($P_{interaction}$ = .29), sinusitis ($P_{interaction}$ = .73), otitis media ($P_{interaction}$ = .69), or for all ARTI ($P_{interaction}$ = .94) diagnoses between the intervention group and the control group postintervention (Supplementary Tables 11–14, respectively). For sore throat, antibiotic prescribing increased in the intervention group compared with the control group postintervention ($P_{interaction}$ = .047; Supplementary Table 15).

Discussion

Comparison with existing literature

We report a non-significant 6.9% absolute reduction of antibiotic prescribing for acute bronchitis in the intervention group compared with the control group. In contrast, our previous intervention, delivered to a smaller pool of registrars with more local granularity, resulted in a statistically significant 16% absolute reduction [19]. This disparity may be due to a lack of peer–peer interaction in our workshops which has previously been identified as useful to GPs in terms of acceptability and implementation of an antibiotic stewardship intervention [34]. In particular, we suspect that considerable supervisor engagement was lost due to the online-only format and lack of face-to-face workshop options.

Within the intervention group, unadjusted antibiotic prescribing proportions decreased from 70% prescription for bronchitis in the pre-intervention phase, to 62% in the postintervention phase. Previous uncontrolled antibiotic stewardship interventions in primary care have reported absolute reductions of antibiotic prescribing of 11% [35] and 25% [10].

In controlled studies, a cluster-randomized trial in 88 Dutch practices included an educational intervention as well as a feedback element [11]. This intervention resulted in a 7.6% absolute reduction in the volume of dispensed antibiotics for RTIs, compared with a 0.4% reduction in the control group [11]. Another cluster-randomized trial in 259 practices across 6 European countries reported a 9% absolute reduction in the antibiotic prescribing rate for RTIs for an intervention focussed on enhanced communication training compared with the control group [12]. The interventions from these two studies were comparable to ours and resulted in a comparable absolute reduction in the intervention groups. A long-term follow-up [36] of a cluster-randomized controlled trial [37] reported a 30% absolute reduction in antibiotic prescribing for upper RTIs in their intervention group, compared with a 1% absolute reduction in the control group, 18 months after the intervention [36]. This effect size is much larger than ours; however, this is not comparable with our primary outcome of acute bronchitis and differences with our secondary outcome may be attributable to the complexity of their intervention, incorporating clinical guidelines, monthly prescribing review meetings, doctor–patient communication skills training, and education materials for caregivers [36].

Regarding systematic review results, antimicrobial stewardship programs were associated with a 10% (95% CI, 4%–15%) absolute reduction in antibiotic prescriptions [9], although this systematic review and meta-analysis was not limited to primary care settings or to respiratory infections. Another review reported a 12% average absolute reduction of antibiotic prescribing for RTIs following physician-targeted interventions [14]. Both of these reviews report higher, but comparable absolute reductions in antibiotic prescribing compared with our findings.

A pre- and postantibiotic stewardship intervention study with a pragmatic, randomized controlled approach reported a non-significant reduction in systemic antibiotic prescribing of their intervention group compared with control ($P_{\text{interaction}} = .850$) [38]. This study differed from ours in that it was randomized and their intervention included a public commitment charter, a patient information leaflet, and a non-prescription pad [38], whereas ours focus was on an educational package, including enhanced knowledge and communication skills, which has previously been shown to be an effective and cost-effective antibiotic stewardship component [36, 39].

Strengths and limitations

The high response rate of the ReCEnT study in which our trial was nested is a strength [40]. In ReCEnT, prescribing is tightly linked to the diagnosis/problem for the prescription. We also directly measured registrar behaviour (prescribing) as the outcome of a behaviour-focussed intervention—rather than prescriptions dispensed. Also, in Australia, there is an increasing proportion of private prescriptions for antimicrobials (i.e. prescriptions that are not government-subsidized and thus not detectable in national dispensing datasets) [3]. Another strength is the large number of potential confounding variables measured in the ReCEnT study (see below).

This intervention is integrated into regular, ongoing GP training, which avoids the risk of a single intervention having a temporary effect on prescribing. However, the supervisor intervention was only delivered as a real-time intervention in the first year of the intervention (2021). In subsequent years, a recording of the original webinar was supplied to supervisors. This limitation may have resulted in reduced supervisor engagement (and, thus, less effective 'modelling' and 'training' elements of the intervention functions of the COM-B model) [18].

Randomization of registrars to intervention or control was not practicable in the real-world context of Australian GP Training. Assignment was, of necessity, at the level of training organization. The large number of potential confounding variables measured in ReCEnT, however, allowed for fine-grained adjustment for potential confounding in our analyses. A consequence, though, of the imbalance in intervention and control RTO participant numbers is that we had fewer participating registrars (corresponding to less diagnoses) in the control group. This may have limited our statistical power.

Covid-lockdown data were not incorporated into our analysis. It is possible that regional lockdowns may have influenced the spread/spectrum of respiratory infections (and subsequent antibiotic prescribing rates). This influence may have occurred between control and intervention regions, or even within the same regions.

Deviations from protocol

A component of the planned intervention, emailing of an electronic copy of a waiting room/treatment room poster on antibiotic stewardship, was not delivered due to logistical issues.

In our protocol, we planned to conduct an interim analysis following ReCEnT data collection for the first half of 2022 and further analyses, if possible, following ReCEnT data collection for the second half of 2022 and for the second half of 2023. The three analyses were provisionally scheduled due to uncertainties regarding the continuation of the ReCEnT study (and the GP Training Research Unit performing it) with the Australian General Practice Training transition from the RTOs to the RACGP in early 2023. The eventual circumstances were of continued operation of both, but with considerable pre- and posttransition disruption. As a result, the two initial planned analyses were not performed.

Implications

The statistically non-significant reduction in prescribing following this intervention, compared with our previous intervention, indicates that it may be challenging to deliver complex, multi-modal interventions at a large scale in an online format. It appears that face-to-face engagement at a local level may be important for the efficacy of such behaviour change interventions [18]. Considering this, together with the absolute reduction in antibiotic prescribing for bronchitis (which could be considered clinically significant) suggests that iteration of the logistics of delivery and further evaluation of the intervention as part of registrars' training program would be reasonable.

Conclusion

We did not find a statistically significant difference in antibiotic prescribing between the intervention and control groups. The lack of statistical significance and reduced effect size compared with a smaller, earlier face-to-face intervention suggests issues with scalability of educational interventions targeting clinical behaviours in the context of an expanded national GP training program.

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Supplementary data

Supplementary data is available at *Family Practice Journal* online.

Conflict of interest

The authors declare no conflicts of interest.

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Patient Consent Statement

Patients were not involved in the design or conduct of this study.

Data Availability

The data underlying this article cannot be shared publicly due to the advice of the relevant Human Research Ethics Committee.

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