



Short Communication

Similarities and differences in antimicrobial prescribing between major city hospitals and regional and remote hospitals in Australia

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ABSTRACT

Many regional and remote hospitals (RRHs) do not have the specialist services that usually support antimicrobial stewardship (AMS) programmes in major city hospitals. It is not known if this is associated with higher rates of inappropriate antimicrobial prescribing. The aim of this study was to identify similarities and differences in antimicrobial prescribing patterns between major city hospitals and RRHs in Australia. The Australian Hospital National Antimicrobial Prescribing Survey (H-NAPS) datasets from 2014, 2015 and 2016 (totalling 47,876 antimicrobial prescriptions) were analysed. The antimicrobial prescribed, indications for use, documentation of indication, recording of a review date and assessment of the appropriateness of prescribing were evaluated. Overall, inappropriate prescribing of antimicrobials was higher in RRHs than in major city hospitals (24.0% vs. 22.1%; $P < 0.001$). Compared with major city hospitals, inappropriate prescribing of ceftriaxone was higher in RRHs (33.9% vs. 27.6%; $P < 0.001$), as was inappropriate prescribing for cellulitis (25.7% vs. 19.0%; $P \leq 0.001$). A higher rate of inappropriate prescribing was noted for some high-risk infections in RRHs compared with major city hospitals, including Gram-positive bacteraemia with sepsis (12.6% vs. 6.5%; $P = 0.004$), empiric therapy for sepsis (26.0% vs. 12.0%; $P < 0.001$) and endocarditis (8.2% vs. 2.7%; $P = 0.02$). To the authors' knowledge, this is the largest study to date comparing antimicrobial prescribing of RRHs with major city hospitals. A key finding was that antimicrobial prescribing was more frequently inappropriate for some high-risk infections treated in RRHs. Targeted strategies that support appropriate antimicrobial prescribing in RRHs are required.

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1. Introduction

Many regional and remote hospitals (RRHs) do not have the specialist resources that usually support antimicrobial stewardship (AMS) programmes in major city hospitals [1]. Studies from a number of countries have highlighted that the uptake of AMS activities in RRHs is more limited compared with major city hospitals [1–5], and that RRHs face unique challenges in delivering AMS programmes [6,7]. It is not known if this is associated with higher rates of inappropriate antimicrobial prescribing. The lack of infor-

mation on antimicrobial prescribing practices in RRHs limits the development of tailored AMS interventions.

The aim of this study was to identify similarities and differences in antimicrobial prescribing patterns between major city hospitals and RRH in Australia using data submitted through the Hospital National Antimicrobial Prescribing Survey (H-NAPS).

2. Materials and methods

H-NAPS is a standardized antimicrobial prescribing point prevalence auditing programme. Hospital-based auditors capture patient-specific information such as demographics, antimicrobial drugs prescribed, allergies, renal impairment and other clinical comorbidities, indication for antimicrobial use, documentation of the intended duration of antimicrobial therapy and microbiology results. The local hospital's nominated assessor determines the ap-

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appropriateness of each antimicrobial prescription. An inappropriate antimicrobial prescription is characterized by lack of concordance with national or local prescribing guidelines (including antimicrobial choice, dose, route and duration of therapy), or where the assessor deems that the prescription is not a reasonable alternative to those listed within guidelines (based on additional documented clinical factors). An antimicrobial prescription may also be classified as inappropriate if an antimicrobial is not indicated, the patient has an allergy to the antimicrobial chosen or there is a serious drug interaction present. Surgical prophylaxis for >24 h is also considered inappropriate (except if endorsed by guidelines) [8]. Local hospitals enter their audit results into a central online portal.

Data collected from Australian hospitals using H-NAPS in 2014, 2015 and 2016 were accessed. Only data collected as a hospital wide point prevalence study, a repeat/serial point prevalence study or a random sample were included in the analysis. Audits described as directed or 'other' (which were likely to target certain drugs, conditions or units/wards) were excluded. Specialist psychiatric and specialist alcohol/drug hospitals were excluded due to limited antimicrobial prescribing. Private hospitals were also excluded as they are predominately located in major cities. Prescriptions categorized in H-NAPS as 'medical prophylaxis' were excluded as medical prophylaxis is far more commonly prescribed in major city hospitals and with a high degree of appropriateness (over 90%) [8]. Inclusion of medical prophylaxis could have positively skewed the overall appropriateness of antimicrobial prescribing in major city hospitals.

Data were divided into two categories based on the Australian Statistical Geography Standard Remoteness Area (ASGS-RA) classifications: major city hospitals and RRHs (consisting of inner regional, outer regional, remote and very remote hospitals) [9]. The most common conditions treated with an antimicrobial and the most common antimicrobials prescribed were identified for each category.

Overall appropriateness of antimicrobial prescribing and appropriateness of prescribing for common conditions and antimicrobials were calculated. The number of prescriptions without an indication or a review date documented, and the proportion of intravenous antimicrobial orders were determined. Appropriateness of antimicrobial prescribing for high-risk infections (defined as endocarditis, febrile neutropenia, meningitis, prosthetic joint infection and sepsis) were calculated. Pearson Chi-square test (χ^2 test) was performed in SAS 9.4 (SAS Institute Inc., Cary, NC, USA) to detect any differences between the two groups.

The collection and analysis of data from H-NAPS was approved by Melbourne Health's Human Research Ethics Committee (Approval No. QA2013066).

3. Results

In total, 47 876 antimicrobial prescriptions were included in the analysis, comprising 31 579 (65.96%) from major city hospitals, 9652 (20.16%) from inner regional hospitals, 5035 (10.52%) from outer regional hospitals, 1088 (2.27%) from remote hospitals and 522 (1.09%) from very remote hospitals. In total, RRHs contributed 16 297 (34.04%) antimicrobial prescriptions.

3.1. Most common conditions

The five most common conditions for which antimicrobials were prescribed in major city hospitals and RRHs are listed in Table 1.

Community-acquired pneumonia (CAP) was the most common condition for which an antimicrobial was prescribed across both categories, but was more likely to be an indication for an antimicrobial to be prescribed in RRHs compared with major city hospitals ($P < 0.001$). Cellulitis, infective exacerbation of chronic obstructive pulmonary disease (COPD) and urinary tract infections (UTIs)

Table 1
Most common conditions for which antimicrobials were prescribed (%^a, n)^{a,b} and the most common antimicrobials prescribed (%^a, n).

Ranking	Most common conditions		Most common antimicrobials	
	Major city hospitals (n=31 579)	Regional and remote hospitals (n=16 297)	Major city hospitals (n=31 579)	Regional and remote hospitals (n=16 297)
1	Community-acquired pneumonia (10.63%, 3358)	Community-acquired pneumonia (18.87%, 3075)	Cefazolin (9.37%, 2960)	Ceftriaxone (13.23%, 2156)
2	Surgical prophylaxis (9.68%, 3056)	Cellulitis/erysipelas (7.64%, 1245)	Piperacillin-tazobactam (8.46%, 2673)	Cefazolin (8.15%, 1329)
3	Urinary tract infection (5.52%, 1742)	Urinary tract infection (6.55%, 1068)	Ceftriaxone (8.21%, 2593)	Doxycycline (7.74%, 1262)
4	Sepsis: empirical therapy (organism unknown) (3.96%, 1252)	Surgical prophylaxis (6.50%, 1059)	Amoxicillin-clavulanic acid (7.61%, 2404)	Flucloxacillin (7.17%, 1168)
5	Hospital-acquired pneumonia (3.60%, 1136)	Chronic obstructive pulmonary disease – infective exacerbation (5.69%, 928)	Metronidazole (7.18%, 2268)	Metronidazole (6.81%, 1110)
	Other conditions ^c		Other antimicrobials ^c	
	Major city hospitals (n=31 579)	Regional and remote hospitals (n=16 297)	Major city hospitals (n=31 579)	Regional and remote hospitals (n=16 297)
	Cellulitis (3.34%, 1056)	Sepsis: empirical therapy (organism unknown) (3.28%, 535)	Flucloxacillin (3.96%, 1249)	Amoxicillin-clavulanic acid (6.11%, 996)
	Chronic obstructive pulmonary disease – infective exacerbation (2.88%, 909)	Hospital-acquired pneumonia (2.14%, 348)	Doxycycline (3.95%, 1248)	Piperacillin-tazobactam (5.95%, 970)

^a Excludes indications listed as 'Other' and 'Indication unknown - pathogen unknown'.

^b The Australian Hospital National Antimicrobial Prescribing Survey does not capture data on the total number of presentations for conditions, and therefore the data reflect only those conditions treated with an antimicrobial. This ranking is influenced where multiple antibiotics are prescribed for the one condition. For example, community-acquired pneumonia would be counted as an indication twice if both doxycycline and amoxicillin were prescribed, whereas cellulitis would only be counted once if treated with flucloxacillin.

^c These are conditions or antimicrobials that do not appear in the five most common of their category (e.g. major city or regional and remote hospitals), but do appear in the alternative category. It is provided for comparison purposes.

Table 2
Rate of inappropriate antimicrobial prescribing for common indications and antimicrobials.

	Major city hospitals	Regional and remote hospitals	P-value
Conditions			
Cellulitis	19.03% (201/1056)	25.70% (320/1245)	<0.001
Chronic obstructive pulmonary disease – infective exacerbation	34.21% (311/909)	34.70% (322/928)	0.827
Community-acquired pneumonia	29.39% (987/3358)	26.73% (822/3075)	0.02
Urinary tract infection	24.40% (425/1742)	22.28% (238/1068)	0.2
Surgical prophylaxis	48.04% (1468/3056)	36.45% (386/1059)	0.001
Hospital-acquired pneumonia	22.18% (252/1136)	23.85% (83/348)	0.515
Antimicrobials			
Ceftriaxone	27.61% (716/2593)	33.86% (730/2156)	<0.001
Cefazolin	34.56% (1023/2960)	27.24% (362/1329)	<0.001
Doxycycline	21.47% (268/1248)	12.36% (156/1262)	<0.001
Amoxicillin-clavulanic acid	32.65% (785/2404)	30.22% (301/996)	0.166
Flucloxacillin	11.69% (146/1249)	13.61% (159/1168)	0.155
Metronidazole	28.40% (644/2268)	27.75% (308/1110)	0.695
Piperacillin-tazobactam	19.00% (508/2673)	22.68% (220/970)	0.014

were also more common indications in RRHs compared with major city hospitals ($P<0.001$).

3.2. Most common antimicrobials

The five most common antimicrobials prescribed in major city hospitals and RRHs are listed in Table 1. Ceftriaxone was more frequently prescribed in RRHs compared with major city hospitals ($P<0.001$). Flucloxacillin and doxycycline were also more commonly prescribed in RRHs compared with major city hospitals ($P<0.001$). Cefazolin and piperacillin-tazobactam were more commonly prescribed in major city hospitals compared with RRHs ($P<0.001$).

3.3. Appropriateness of antimicrobial prescriptions

Overall, inappropriate prescribing of antimicrobials was higher in RRHs compared with major city hospitals [23.91% (3897/16 297) vs. 22.16% (6999/31 579); $P<0.001$].

The appropriateness of antimicrobial prescribing was analysed for common indications and antimicrobials (Table 2). RRHs had a higher rate of inappropriate antimicrobial prescriptions for cellulitis ($P<0.001$). Inappropriate antimicrobial prescribing was higher in major city hospitals for CAP ($P=0.02$). There was no significant difference between major city hospitals and RRHs when comparing inappropriate antimicrobial prescribing for UTIs ($P=0.2$) and infective exacerbation of COPD ($P=0.83$).

Inappropriate prescribing of ceftriaxone was higher in RRHs compared with major city hospitals ($P<0.001$), as was inappropriate prescribing of piperacillin-tazobactam ($P=0.01$). Inappropriate prescribing of cefazolin ($P<0.001$) and doxycycline ($P<0.001$) was higher in major city hospitals compared with RRHs.

3.4. Surgical prophylaxis

There were proportionately more antimicrobial prescriptions for surgical prophylaxis in major city hospitals compared with RRHs [9.68% (3056/31 579) vs. 6.50% (1059/16 297); $P<0.001$].

The rate of inappropriate antimicrobial prescribing was high in both categories, with higher rates of inappropriate antimicrobial prescriptions for surgical prophylaxis in major city hospitals compared with RRHs [48.04% (1468/3056) vs. 36.45% (386/1059); $P<0.001$].

3.5. High-risk infections

RRHs contributed 27.13% (1380/5086) of the antimicrobial prescriptions for high-risk infections (Table S1, see online supplementary material). Sepsis was the most commonly treated high-risk infection in both major city hospitals and RRHs.

Appropriateness of antimicrobial prescribing for high-risk infections is shown in Table 3. For known Gram-positive bacteraemia with sepsis and empiric therapy for sepsis, the rate of inappropriate antimicrobial prescribing in RRHs was higher than in major city hospitals ($P=0.004$ and $P<0.001$, respectively). Higher rates of inappropriate antimicrobial prescribing were also found in RRHs compared with major city hospitals for all types of endocarditis ($P=0.02$). There was no significant difference between inappropriate antimicrobial prescribing for prosthetic joint infections ($P=0.2$), febrile neutropenia ($P=0.6$) and known Gram-negative bacteraemia with sepsis ($P=0.7$).

3.6. Other measures

The proportion of intravenous antimicrobial prescriptions was higher in RRHs than in major city hospitals [55.76% (9088/16 297) vs. 53.80% (16 990/31 579); $P<0.001$]. Absence of a documented indication for the antimicrobial prescription was higher in RRHs compared with major city hospitals [22.47% (3662/16 297) vs. 19.37% (6116/31 579); $P<0.001$]. Similarly, absence of a documented review or stop date for antimicrobials was higher in RRHs compared with major city hospitals [68.35% (7998/11 702) vs. 63.92% (14 254/22 299); $P<0.001$] (2015 and 2016 data only).

Table 3
Rate of inappropriate antimicrobial prescribing for high-risk infections^a.

	Major city hospitals	Regional and remote hospitals	P-value
Endocarditis	2.7% (7/256)	8.2% (8/98)	0.02
Febrile neutropenia	10.2% (62/609)	11.5% (21/183)	0.6
Meningitis	11.9% (28/235)	13.7% (7/51)	0.7
Prosthetic joint infection	4.3% (10/235)	7.6% (8/105)	0.2
Sepsis			
Directed therapy – Gram-positive bacteraemia	6.4% (38/592)	12.6% (28/223)	0.004
Directed therapy – Gram-negative bacteraemia	12.7% (67/527)	11.9% (22/185)	0.7
Empirical therapy – organism unknown	11.98% (150/1252)	26.0% (139/535)	<0.001

^a % = number of inappropriate prescriptions for indication/total number of prescriptions for that indication.

4. Discussion

This study comparing antimicrobial prescribing patterns of RRHs with major city hospitals has provided valuable insights that will guide AMS initiatives targeted at RRHs. Of concern is the finding that prescribing of antimicrobials for some high-risk infections outside of major city hospitals is frequently inappropriate. Timely treatment with appropriate antimicrobials is important to reduce morbidity and mortality from high-risk infections, such as sepsis [10]. High-risk infection management in RRHs therefore requires further review and action so that the outcome of care is equivalent regardless of the location of the hospital.

The results of this study indicate that it would be valuable for other countries to identify if similar variation exists in their antimicrobial prescribing practices.

There are several strategies that may improve the appropriateness of antimicrobial prescribing in high-risk infections in RRHs. While RRHs may have access to expert input (e.g. from a microbiologist through existing pathology networks or an infectious diseases specialist via telehealth), it is important that this advice is sought routinely. A set of high-risk infections where there is a requirement to seek expert advice may be of value, such as Gram-positive bacteraemia or endocarditis. Where RRHs do not have adequate access to timely expert infectious diseases advice, they must be supported to develop formal arrangements [11] so that an appropriate and consistent level of service is achieved. Structured programmes, such as the SEPSIS KILLS [12] initiative delivered by the Clinical Excellence Commission in Australia, have been effective in regional hospitals. Programmes targeting sepsis management have also been trialled in critical access hospitals in the USA [13], and these findings suggest that there is an ongoing need for work in this area.

The current work has highlighted other priority areas for AMS in RRHs, including initiatives that optimize ceftriaxone and piperacillin-tazobactam use. Ceftriaxone appears to be an important focus for intervention given that it was the most common antimicrobial used in RRHs. Inappropriate use of ceftriaxone in RRHs has been identified previously [14]; however, published interventions to improve prescribing of ceftriaxone in RRHs are limited. In one Australian study, Bond et al. reported an education-based intervention at a large regional referral hospital. Local data and individual prescriber/team e-mails were used to reduce the number of patients receiving ceftriaxone for mild-to-moderate CAP infection [15]. The authors concluded that the intervention could be 'readily transferred to other settings' [15]. The higher rate of inappropriate prescribing of piperacillin-tazobactam in RRHs was a surprise, although it was much less commonly used than in major city hospitals. The higher rate of inappropriate antimicrobial prescribing for

cellulitis in RRHs is also likely to be an important target because it is such a common condition in RRHs.

Several other indicators were identified for improvement [e.g. documentation of antimicrobial indication and review dates, durations of intravenous (IV) antimicrobial therapy], and these may be suitable initial focuses in low-resource settings. The higher proportion of intravenous antimicrobial therapy in RRHs could suggest that IV to oral switch of antibiotics may not have been occurring as frequently in this setting as in major city hospitals. A centrally coordinated AMS programme involving 47 private hospitals in South Africa also concluded that focusing on a few crucial interventions (such as excessive antibiotic duration) could yield substantial returns with the least effort in low-resource settings [16].

There were also some positive findings in the analysis for antimicrobial prescribing in RRHs, including a higher frequency of prescriptions for narrow-spectrum antimicrobials such as flucloxacillin and doxycycline, compared with major city hospitals. The rates of inappropriate antimicrobial prescribing for surgical prophylaxis were higher in major city hospitals, and this appears to align with the higher rate of inappropriate prescribing of ceftazidime (a common antimicrobial used for this indication). It is possible that more complex surgeries on more complex patients are performed in major city hospitals, which might be associated with inappropriately prolonged prophylaxis. In major city hospitals, antimicrobial prescribing for CAP was more often inappropriate. This may be because more complex patients are perceived to require broader-spectrum antibiotics than guidelines generally advise. The higher rate of inappropriate prescribing of doxycycline in major city hospitals was surprising and warrants further investigation.

This study was not able to identify why differences in the appropriateness of antimicrobial prescribing existed between major city hospitals and RRHs. There may be justifiable clinical reasons for the variation that are not acknowledged in the guidelines, or are not being documented explicitly by the treating doctor for the auditors to consider. However, barriers to AMS programme delivery in RRHs have been identified previously, including a lack of access to staff who are skilled in AMS (including infectious diseases physicians and pharmacists with training in infectious diseases) [1], geographical isolation from larger centres [16,17] and a lack of information technology resources [18]. Given these barriers, RRHs face challenges in applying initiatives that have been implemented predominately in major city hospitals. Further research specific for RRHs is required [7]. This includes identifying and evaluating strategies that may exist in individual RRHs but are not published or reported externally.

This study has some other potential limitations. The sites who contribute data to H-NAPS do so voluntarily, and therefore the

data do not include all Australian hospitals. However, over 47 000 prescriptions were available for analysis, which provided a large sample size. H-NAPS data were predominately collected using a point prevalence model. In large hospitals or hospitals with limited resources, only a sample population of patients may be reviewed on the day of the survey. Not all hospitals provide data on the total number of patients in the sample; therefore, it is difficult to determine certain measures accurately, such as the proportion of patients on antimicrobials. H-NAPS data were only collected for patients prescribed antimicrobials, and this survey did not capture data on instances where antimicrobials should have been prescribed but were not. The data also cannot account for diagnostic error. H-NAPS excludes antimicrobial prescriptions administered under programmes such as Hospital in the Home [e.g. outpatient parenteral antimicrobial therapy (OPAT)]. An OPAT-specific NAPS is currently being piloted [19]. The assessment of antimicrobial appropriateness is undertaken by hospital-appointed assessors at each site, and variability in assessing appropriateness has been reported previously [20].

The use of ASGS-RA classifications has limitations in that small hospitals can be located within a major city location. Given that the smaller hospitals in the major city classification would contribute only a small number of prescriptions, this is unlikely to have influenced the findings of this study. It is recognized that creating a dataset inclusive of inner regional, outer regional, remote and very remote hospitals represents a wide range of hospital structures and resources, and that the factors driving antimicrobial prescribing choices may differ within the dataset. Greater analysis of individual ASGS-RA classifications may be warranted. No specific information on the AMS resources at individual hospitals was available to directly evaluate the impact of resourcing on the appropriateness of antimicrobial prescribing.

A strength of this study was the use of appropriateness of antimicrobial prescribing as a marker of judicious use, rather than usage data. Although there may be differences in the case mix of patients presenting to different hospitals, this methodology uses the indication attributed by the treating clinician, and therefore adjusts for obvious situations where different antimicrobials are recommended (e.g. variation in methicillin-resistant *Staphylococcus aureus* epidemiology) or local variation for individual patient clinical factors as documented by the treating team.

5. Conclusion

This study provided valuable insight into the similarities and differences in antimicrobial prescribing between RRHs and major city hospitals. High-risk infections are being managed in RRHs, and the appropriateness of antimicrobial prescribing for some of these high-risk infections is lower than in major city hospitals. The management of cellulitis and the use of ceftriaxone were also identified as areas for improvement in RRHs. These findings will assist the tailoring of AMS initiatives to optimize the management of patients requiring antimicrobials in RRHs.

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Declarations

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Competing interests

DCMK has sat on advisory boards for Merck, Sharpe and Dohme (MSD), and received financial/travel support unrelated to the current work from Roche and MSD. JLB, TRS, RJ and KLB report no competing interests.

Ethical approval

Collection of the H-NAPS data is approved by Melbourne Health's Human Research Ethics Committee (QA2013059).

Supplementary material

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.ijantimicag.2018.10.009.

References

- [1] James R, Luu S, Avent M, Marshall C, Thursky K, Buising K. A mixed methods study of the barriers and enablers in implementing antimicrobial stewardship programmes in Australian regional and rural hospitals. *J Antimicrob Chemother* 2015;70:2665–70.
- [2] James R, McIntosh K, Luu S, Cotta M, Marshall C, Thursky K, et al. Antimicrobial stewardship in Victorian hospitals: a statewide survey to identify current gaps. *Med J Aust* 2013;199:692–5.
- [3] Lusardi K, Kuper K, Coyle E, Garey K. Adherence to IDSA/SHEA antimicrobial stewardship guidelines: results of a nationwide survey. Poster presented at Infectious Diseases Society of America Annual Meeting, Boston, MA, USA.
- [4] Pollack LA, van Santen KL, Weiner LM, Dudeck MA, Edwards JR, Srinivasan A. Antibiotic stewardship programs in U.S. acute care hospitals: findings from the 2014 National Healthcare Safety Network (NHSN) annual hospital survey. *Clin Infect Dis* 2016;63:443–9.
- [5] Reese SM, Gilmartin H, Rich KL, Price CS. Infection prevention needs assessment in Colorado hospitals: rural and urban settings. *Am J Infect Control* 2014;42:597–601.
- [6] Bishop JL, Schulz TR, Kong DCM, Buising KL. A qualitative study of the factors impacting antimicrobial stewardship program delivery in regional and remote hospitals. *J Hosp Infect.* in press. <https://10.1016/j.jhin.2018.09.014>.
- [7] Broom A, Broom J, Kirby E, Gibson A, Davis M. Antibiotic optimisation in 'the bush': local know-how and core-periphery relations. *Health Place* 2017;48:56–62.
- [8] Australian Commission on Safety and Quality in Healthcare. Sydney: Australian Commission on Safety and Quality in Healthcare; 2016.
- [9] Australian Bureau of Statistics. Canberra: Commonwealth of Australia; 2013.
- [10] Groups Antibiotic Expert. Therapeutic guidelines: antibiotic. 15th ed. Melbourne: Therapeutic Guidelines Limited 2014.
- [11] zero Duckett S. Targeting. Supporting the Victorian hospital system to eliminate avoidable harm and strengthen quality of care. Melbourne: Victorian Government 2016.
- [12] Burrell AR, McLaws ML, Fullick M, Sullivan RB, Sindhusake D. SEPSIS KILLS: early intervention saves lives. *Med J Aust* 2016;204:1 e–7.
- [13] Mohr N, Skow B, Wittrock A, Bell A, McDanel J, Fuller B, et al. Improving access to high quality sepsis care in a South Dakota emergency telemedicine network. *RTRC Research & Policy Brief* August 2017:1–4.
- [14] Brownridge DJ, Zaidi ST. Retrospective audit of antimicrobial prescribing practices for acute exacerbations of chronic obstructive pulmonary diseases in a large regional hospital. *J Clin Pharm Ther* 2017;42:301–5.
- [15] Bond SE, Boutlis CS, Yeo WW, Miyakis S. Impact of an antimicrobial stewardship intervention on appropriateness of prescribing for community-acquired pneumonia in an Australian regional hospital. *Intern Med J* 2017;47:582–5.
- [16] Brink AJ, Messina AP, Feldman C, Richards GA, Becker PJ, Goff DA, et al. Antimicrobial stewardship across 47 South African hospitals: an implementation study. *Lancet Infect Dis* 2016;16:1017–25.

- [17] Stevenson KB, Samore M, Barbera J, Hannah E, Moore JW, Gerberding JL, et al. Pharmacist involvement in antimicrobial use at rural community hospitals in four Western states. *Am J Health Syst Pharm* 2004;61:787–792.
- [18] Trivedi KK, Kuper K. Hospital antimicrobial stewardship in the nonuniversity setting. *Infect Dis Clin N Am* 2014;28:281–9.
- [19] Friedman ND, James R, Ingram R, O'Reilly M, Pollard J, Koning S, et al. Antimicrobial stewardship (AMS) in the outpatient parenteral antimicrobial therapy (OPAT) setting. Poster presentation at IDWeek, San Francisco, CA, USA.
- [20] Cotta MO, Spelman T, Chen C, James RS, Liew D, Thursky K, et al. Evaluating antimicrobial therapy: how reliable are remote assessors? *Infect Dis Health* 2016;21:3–10.