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REVIEW

Building on Antimicrobial Stewardship Programs Through Integration with Electronic Medical Records: The Australian Experience

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ABSTRACT

Antimicrobial stewardship (AMS) is well established in Australian hospitals. Electronic medical record (EMR) implementation has lagged in Australia, with two Healthcare Information and Management Systems Society (HIMSS) Stage 6 hospitals and one Stage 7 hospital as of September 2020. Specific barriers faced by AMS teams with paper-based prescribing and medical records include real-time identification of antimicrobials orders; the ability to prospectively monitor antimicrobial use; and the integration of fundamental point of prescribing AMS principles into routine clinical practice. There are few local guidelines to assist Australian hospitals and AMS teams beyond "out of the box" EMR functionality. EMR implementation has enormous potential to positively impact AMS teams through more efficient workflows and the ability to expand the reach and coverage of AMS activities. There are inevitable limitations associated with EMR implementation that must be considered. In this paper, four Australian hospitals share their experience with EMR roll out, AMS customisation and how they have overcome specific barriers in local AMS practice.

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Key Summary Points

Why carry out the study?

Antimicrobial stewardship (AMS) is well established in Australian hospitals; however, electronic medical record (EMR) implementation is in its infancy.

AMS teams face barriers to practice with paper-based prescribing.

We aim to describe how four hospitals overcame these barriers following EMR implementation.

What was learned from the study?

EMR has enabled Australian hospitals to overcome specific barriers in AMS practice; however, it is not without limitations.

EMR has enabled expansion of the four Australian AMS programs described.

AMS specific build features for EMRs are suggested for the Australian setting.

DIGITAL FEATURES

This article is published with digital features, including a summary slide, to facilitate understanding of the article. To view digital features for this article go to https://doi.org/10.6084/m9.figshare.13353293.

INTRODUCTION

Antimicrobial stewardship (AMS) is well established in Australian hospitals following its inclusion in mandatory National Safety and Quality Health Service (NSQHS) Standards in 2013. The AMS model implemented at each institution varies according to local context and resources [1]. Electronic medical records (EMRs) have significant potential to support and complement AMS activities [2–4]; however, Australia has lagged behind other countries with respect to implementation. There is currently no national or state level definition of an EMR in Australia, leading to variable use of the terms EMR and electronic medicines management (EMM). The Healthcare Information and Management Systems Society (HIMSS) analytics Electronic Medical Record Adoption Model lists an eight stage model of EMR adoption with stages from 0 to 7. Stage 0 has no elements of key ancillary clinical systems installed, whereas Stage 5 includes full physician documentation, tracking of nurse task completion and an intrusion prevention system. Stage 6 is often referred as a digital hospital which includes technology-enabled medication and full clinical decision support, while Stage 7 is a complete EMR [5]. Recent data indicated that 30% of Australian public hospitals have implemented an inpatient EMM solution [6], and, as such, HIMSS validation has not been widely adopted in Australia at this time. As of September 2020, there are two Stage 6 and one Stage 7 HIMSS-validated hospitals in Australia, compared with 2040 hospitals at Stage 6 and 255 hospitals at Stage 7 in the United States of America (USA) [7].

In the absence of an EMR, Australian AMS teams face three major barriers in practice: real-time identification of prescribed antimicrobials, the ability to prospectively monitor antimicrobial use, and the ability to integrate fundamental point of prescribing AMS principles into routine clinical practice. National AMS guidelines support EMR implementation [8–10]; however, there is very little published experience from Australia to assist with integration of EMR into existing AMS programs. We aim to describe how four Australian hospitals have overcome these specific practice barriers following the implementation of EMR within their institution, and to provide suggestions for AMS specific build features for new hospitals embarking on a digital transformation. Three of the four hospitals utilise Cerner® PowerChart® (Kansas City, MS, USA). This article is based on

previously conducted studies and does not contain any studies with human participants or animals performed by any of the authors.

THE EXPERIENCE

Princess Alexandra Hospital, Brisbane, Queensland

The Princess Alexandra Hospital (PAH) is an 850-bed tertiary hospital in metropolitan Brisbane. PAH is a HIMSS Stage 6 digital hospital [7]. Prior to EMR go-live, the Infectious Diseases (ID) team identified antimicrobial prescriptions through medical staff and ward pharmacist referrals utilising a combination of telephone, text message, paging service, and random chart review.

The PAH was the first site for complete EMR functionality in Queensland, which is continuing to be implemented across all Queensland Health hospital sites with governance and configurations managed at a state-wide level [11]. An EMR (Cerner) was implemented in a three-stage rollout beginning with adverse drug reactions and allergies recording, then clinical documentation and nursing care tasks including pathology ordering and result reporting, with the final stage being EMM, completed in March 2017. The Intensive Care Unit (ICU) utilises Cerner EMR for most functions; however, medications are managed through MetaVision ICU® (iMDsoft®, Israel) which does not interface with Cerner.

Point of prescribing AMS functionality was built through various features, as shown in Table 1. Clinical alerts were limited to allergy mismatches, extreme doses, and major drug interactions. Documentation of an indication for antimicrobials is mandatory using a free text field.

Reporting and data extraction has changed over time. During the initial build phase, Discern Explorer® functionality was developed for on-demand antimicrobial reports. While useful initially in providing basic reports, a decision was made to invest in developing a comprehensive antimicrobial dashboard which would provide more efficient data extraction along with an enhanced graphical user interface. This was achieved through a local PAH clinical informatics team utilising Qlik Sense® software. Figures 1 and 2 show examples of views seen following implementation of this functionality. This dashboard has since been rolled out and validated at numerous Queensland Health facilities where it is used routinely. Of note, it was invaluable in managing prescribing of piperacillin/tazobactam during the national shortage in 2017 and 2018, facilitating rapid identification and AMS interventions for both newly prescribed and ongoing therapy with this agent. This dashboard, along with the existing EMR functionality, has increased the efficiency of AMS activities, facilitating more frequent and comprehensive review of antimicrobial therapy. Governance of antimicrobial-related EMR functionality, including order sentences, order sets, alerts and AMS dashboards, is managed through the Statewide Antimicrobials Digital Working Group reporting to the Queensland Health Medicines Advisory Committee.

Alfred Health, Melbourne, Victoria

Alfred Health (AH) is a 1000-bed health service in metropolitan Melbourne split across three campuses. Prior to EMM go-live, the AMS team identified antimicrobial prescriptions through pharmacist notifications through stand-alone third-party AMS software, Guidance MS® (Melbourne Health). AMS ward rounds were undertaken at one campus only.

An EMR (Cerner) has been in place since 1999 which has evolved over time to include scanned medical notes, orders, radiology and pathology. Clinical documentation, EMM (including complex medications) and some device integration were implemented in October 2018 and rolled out across all areas of the health service, including ICU. Cancer care is the only therapeutic area that is currently managed through a hybrid system, with chemotherapy currently charted on paper and supportive care medications charted in the EMR.

Point of prescribing AMS functionality was built through various features, as shown in Table 1. Clinical alerts were limited to

Table 1 AMS functionality incorporated into EMR builds at four Australian tertiary teaching hospitals

	Concord Hospital, NSW	Alfred Health, VIC	Princess Alexandra Hospital, QLD	Fiona Stanley Hospital, WA
Antimicrobial agent indications mandatory at time of prescribing	Y (free text)	Y (free text and drop down list)	Y (free text)	N/A
Antimicrobial order sets	Y (limited Cerner PowerPlan[a])	Y (Cerner PowerPlan[a])	Y (Cerner PowerPlan[a])	N/A
Types of antimicrobial order sets in use	Drug based	Drug based	Drug based	N/A
		Disease based	Disease based	
Automatic stop dates for high risk antimicrobials	Y	N (optional for prescribers)	N (optional for prescribers)	N/A
AMS pharmacist electronic referrals	Capable but not in use	Y	Y	Y
Priority dosing for IV antimicrobials	Y (optional)	Y	Y	N/A
Clinical alerts	Limited	Limited	Limited	N/A
Significant drug interactions	Y	Y	Y	N/A
Life threatening allergy mismatch	Y	Y	Y	N/A
Customised order sentences for antimicrobial agents	Y	Y	Y	N/A
Antimicrobial specific report in use	Y	Y	Y	N/A
Identification of high-risk antimicrobial agents	Y	Y	Y	N/A
Ability to link to local policy	Y	Y	Y	N
Data extraction capabilities	Y	Y	Y	N/A
Local antimicrobial dashboard in use	Y (Cerner mPage)	N	Y (Qlik Sense software)	N/A

[a] A PowerPlan is a Cerner-specific set of orders grouped together to enable care for a patient [2]

significant and life-threatening allergy mismatches, drug interactions and renal impairment dosing warnings.

A customised report (Discern Explorer®) was developed to identify all patients prescribed antimicrobial therapy at the time of roll out to facilitate ongoing post-prescription AMS rounds that have previously been described [12]. This report has enabled the AMS team to expand its AMS ward rounds across all three campuses, and to specifically target carbapenem and beta-lactam/beta-lactamase inhibitor combination prescribing. A 'High-Risk Category Worklist' has been enabled for vancomycin and aminoglycoside antibiotics to enable pharmacists to identify patients prescribed these high-risk antimicrobial agents.

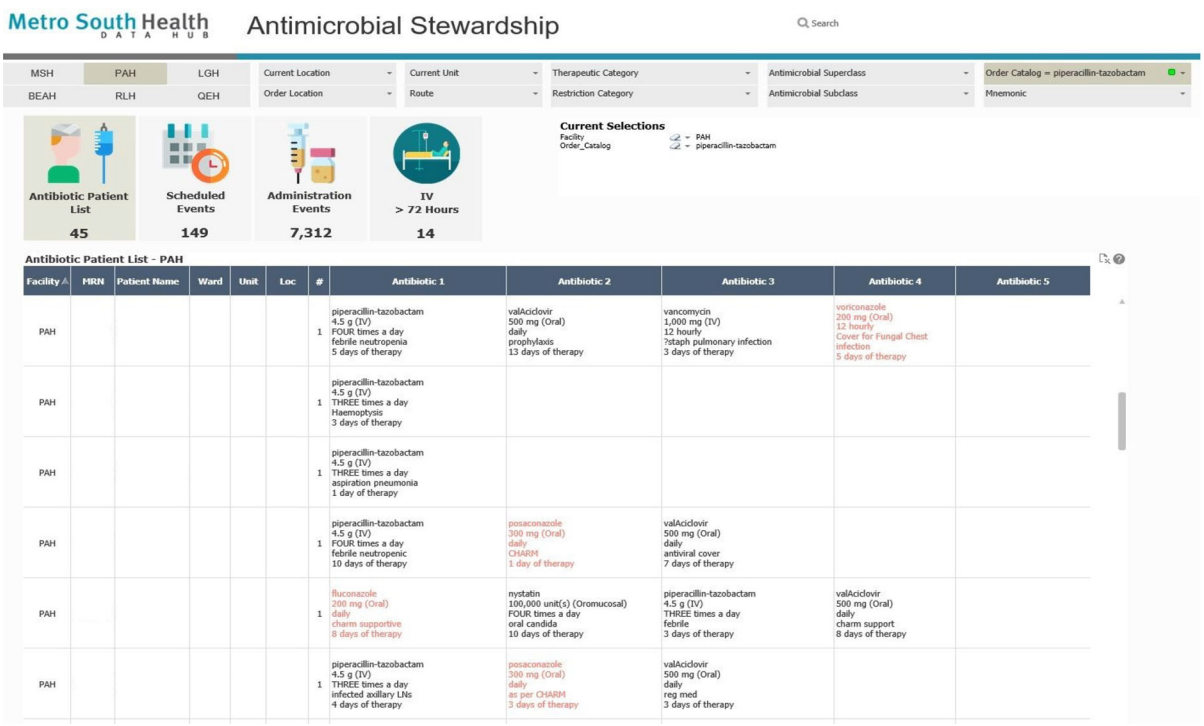

Fig. 1 Princess Alexandra Hospital/District-wide antimicrobial screening view

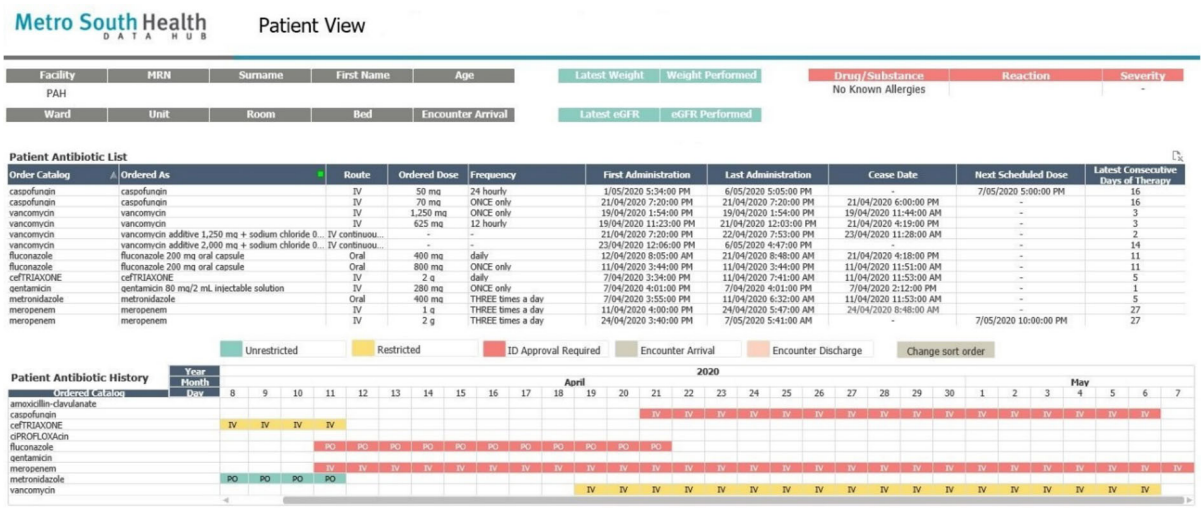

Fig. 2 Princess Alexandra Hospital patient-level antimicrobial therapy view

Fiona Stanley Hospital, Perth, Western Australia

Fiona Stanley Hospital (FSH) is a 783-bed hospital in Perth, Western Australia, that was partially opened in October 2014, with full opening complete in February 2015. Prior to the implementation of an adapted electronic referral system in mid-February 2015, the AMS team identified antimicrobial prescriptions using various methods, including pager, email, and telephone referrals.

An EMR (BOSSnet™, Core Medical Solutions™, South Australia) was rolled out at the time of hospital commissioning in February 2015. Components of BOSSnet rolled out were limited to clinical documentation and integration with third party software required for additional patient management, including pathology and laboratory results, medical imaging/radiology results and clinical documentation within the burns unit. All ICU documentation and medication prescriptions are electronic through MetaVision ICU. Paper documentation remains for all medication administration and clinical observation documentation outside the ICU. Paper documents are scanned and stored in BOSSnet for user access.

AMS functionality is currently limited to the use of third-party software enabling electronic referrals to the AMS team (eReferrals™ (Health Support Services, Perth, Western Australia)) (Table 1). These referrals, which have been previously described, are entered by pharmacists and/or doctors to prompt an AMS team review. Following the implementation and increased utilisation of eReferrals, the AMS team saw a two-fold increase in the number of patients referred for AMS round review when compared to the previously used manual system [13].

Concord Repatriation General Hospital, Sydney, New South Wales

Concord Repatriation General Hospital (CRGH) is a 750-bed health service in metropolitan Sydney. Prior to EMM go-live, the AMS team identified antimicrobial prescriptions through physical review of the paper charts during audit and feedback rounds, and through medical, pharmacy and nursing notifications via a paging system.

An EMR (Cerner) has been in place since 2000 (allergy documentation, radiology, scheduling, pathology results and some orders) with functionality being progressively added. Partial EMM was added in a four-stage rollout over a period of 9 years. Paper records are currently used to prescribe and administer complex infusions such as heparin and patient-controlled analgesia. CRGH was the first hospital in New South Wales to implement EMM with EMR functionality, and therefore some components differ to the state-wide build. The CRGH build is shared with seven facilities across two local health districts, together with components of the state build.

Point of prescribing AMS functionality was built through various features, as shown in Table 1. Verbal approval codes for restricted antimicrobials are provided by the AMS team and documented in the EMR; however, there is no central repository of approval codes with their expiry dates.

The AMS program collaborated with the Health Informatics Unit to develop active surveillance of antimicrobial use with business intelligence tools. As the first Australian public hospital to go-live with EMR, CRGH assessed a suite of tools available to support AMS over three phases. The first phase was using the Qlik Sense® dashboard; however, hospital resources were focussed on the subsequent phases due to greater accessibility for all clinicians and greater integration with Cerner. Learnings have since led to the development of a state-wide NSW dashboard to measure AMS outcomes which is currently in progress. The second phase was a SAP® BusinessObjects™ report to automatically email a spreadsheet of current antimicrobial orders from the EMR to the AMS team at a specific time of day. Finally, an AMS live mPage™ was developed which went live in early 2017. This mPage is a virtual view within Cerner that collates real-time information from the EMR, including microbiology and pathology results, in addition to all current antimicrobial prescriptions (Fig. 3). This mPage has enabled the AMS team to expand their program including facilitation of short, weekly, real-time AMS rounds with surgical teams to develop collaborative antibiotic plans, with discussions entered directly into the mPage. Due to improved efficiencies in identifying patients actively prescribed an antimicrobial, existing AMS rounds took significantly less time to complete [14].

Overarching governance for EMR changes, including the AMS Live mPage is conducted at

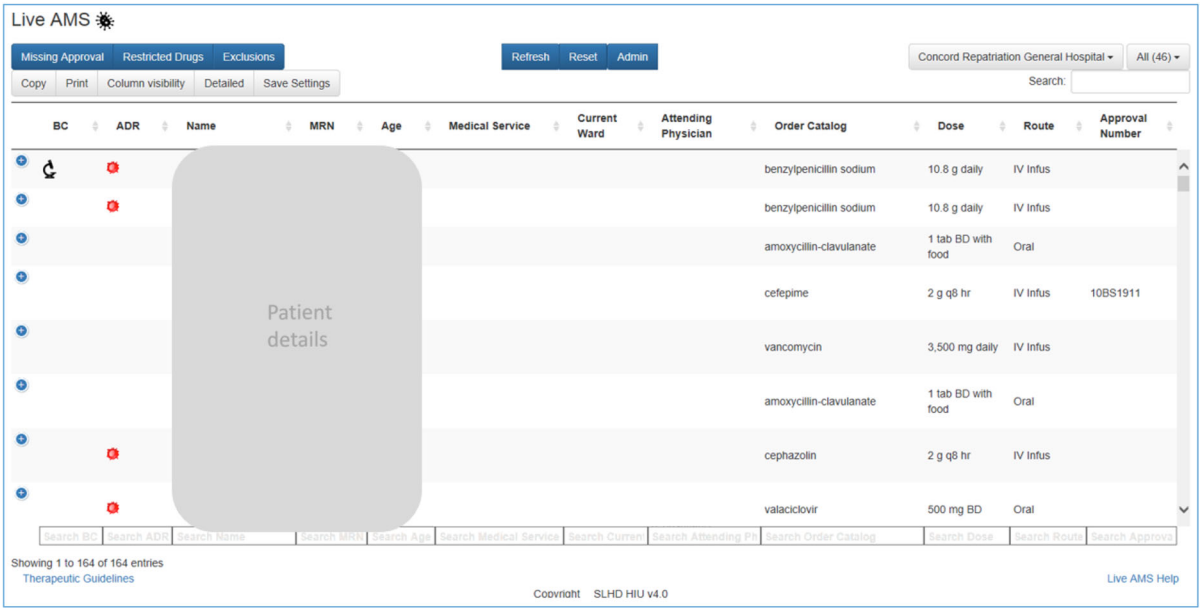

Fig. 3 Concord Repatriation General Hospital interactive mPage view

Local Health District level together with clinicians and the Health Informatics Unit.

DISCUSSION

We describe EMR implementation in four Australian hospitals in the context of antimicrobial stewardship and demonstrate the ability of EMRs to overcome specific barriers faced in local AMS practice. Two of the four hospitals described have invested in business intelligence tools to assist with utilisation of EMR for AMS activities.

EMR roll-out is still in its early stages in Australia, with less than one-third of hospitals having implemented EMM in 2020 [6]. Comparatively, a survey of 3538 hospitals in the USA identified that 81% of hospitals had adopted at least a basic electronic health record in 2015; however, there was wide variation in the functionality of these systems [15]. At this time, there are no unifying Australian guidelines available to direct AMS-specific EMR content build, with many individual hospitals developing specific local content to meet national AMS guidelines [8–10, 16]. Australia benefits from having a coordinated national Antimicrobial Resistance (AMR) strategy [17], and, importantly, the four hospitals described in this paper had active AMS programs in place, with established processes, teams and governance prior to EMR go-live. Cerner is currently the predominant EMR vendor for health services on the east coast of Australia, with other EMRs including Epic® (Verona, Wisconsin), BOSSnet and MedChart (DXC Technology, Macquarie Park, NSW) being implemented in smaller numbers across the remainder of other Australian hospitals. Much of the available published literature on the role of EMR in AMS is based on the experience of hospitals in the USA [2–4]; however, differences in health service models limits the direct applicability to the Australian healthcare system. EMRs provide opportunities to enhance AMS programs; however, there are also several limitations that should be considered.

Strengths of EMR for AMS in Australia

As described by the individual hospitals, the implementation of EMR has enabled expansion of AMS programs in response to local challenges and need. While it is still early in the broader roll out of EMR nationally, and as such large-

scale data are not yet available, there is emerging evidence that EMR has enabled Australian AMS teams to identify patients prescribed antimicrobial therapy in real-time with increased efficiency [18]. Doukas et al. [14] reported an increase number of antimicrobials reviewed and a reduction in time taken to complete AMS rounds from 58 to 44 min following the implementation of EMM. Similarly, Rawlins et al. [13] reported more timely AMS round reviews, increased adherence to advice and reduced use of key antimicrobials over a 12-month period following implementation of the electronic referral system for AMS ward rounds. Patient identification in paper-based hospitals relies on pharmacy dispensing records, web-based antimicrobial approval systems or through ad hoc communication channels. Real-time patient identification has enabled AMS teams to prioritise and triage patients for AMS review, including targeting specific antimicrobial agents (e.g. during periods of supply shortages) and antimicrobial classes (e.g. carbapenems).

Broader reviews of the general ability of EMRs to support healthcare have shown a number of advantages, including improved information transfer and organisation efficiency, while effects on mortality, readmissions, total costs and patient and provider experience remain uncertain [19]. There are limited data to date to support AMS-specific outcomes following EMR implementation, with reduced antimicrobial utilisation [20, 21] and reduced rates of *Clostridioides difficile* [20] reported. Well-designed studies are required to further demonstrate the impact of EMR implementation on AMS process and clinical outcomes.

As described by Pogue et al., the implementation of a Cerner EMR has the ability to facilitate supplementary elements of AMS, as identified by the Infectious Diseases Society of America [2, 22]. Creation of customised antimicrobial order sentences and order sets within EMRs enables AMS teams to drive evidence-based care with the aim of enhancing guideline adherence and pathway utilisation, antimicrobial dose optimisation and education [2]. Within the Cerner sites described in this paper, order sets have been rolled out to assist with the prescribing of both complex, high-risk and narrow therapeutic index antimicrobials in addition to syndromic order sets. Internationally, Krive et al. [23] demonstrated reduced mortality, readmission and length of stay over a 5-year period following the implementation of a syndrome-specific order set for community-acquired pneumonia.

Documentation of indication is a key element of antimicrobial prescribing [16, 24]. The 2018 rate of antimicrobial indication documentation in Australian hospitals was 80%, which is below the suggested best-practice target of 95% [25]. Despite incremental improvement in this metric following the implementation of Australian AMS programs, EMR provides the opportunity to mandate this. Doukas et al. demonstrated improvement in indication documentation for electronically prescribed antimicrobial orders from 73 to 97% following EMR implementation ($p < 0.0001$) [14].

The Australian NSQHS Standards (Version 2) mandate the need to review antimicrobial prescribing and use, while evaluating AMS program performance and identifying areas for improvement [16, 26]. Suggested process, outcome and balancing measures are available [10], and we suggest prioritising the process measures listed in Table 2 to be measurable through the EMR at the time of go-live. Reports to facilitate real-time data collection require careful validation prior to use to ensure accuracy of information, and will ideally enable the ability to benchmark process and outcome measures between hospitals.

National level volume-based surveillance is available through voluntary participation in the National Antimicrobial Utilisation Surveillance Program [27]. Contributions have generally been restricted to pharmacy dispensing and distribution data, and reported as defined daily doses per 1000 bed-days. EMR roll out will enable calculation of antimicrobial days of therapy for all patient groups, the preferred metric for assessing the impact of AMS interventions [28]. This will further enable expansion of volume-based surveillance to paediatric populations as well as facilitate international benchmarking in the adult setting.

Table 2 Suggested go-live EMR process measures for Australian AMS programs

1. Days of antimicrobial therapy
2. Documentation of indication for antimicrobial therapy
3. Antimicrobial allergy mismatch

Limitations of EMR for AMS in Australia

AMS is a complex field, with successful programmes requiring a coordinated approach, including governance systems, guideline-driven practice, antimicrobial restriction, audit and feedback and incorporation of behaviour change strategies [10]. The ultimate aim of an AMS program is to optimise antimicrobial use. While EMRs are able to address some of the 'low hanging fruit' at the point of antimicrobial prescribing, they cannot address the cultural, contextual and behavioural factors that are known to influence antimicrobial prescribing [29–31]. By improving the efficiency of AMS teams through faster patient identification, reduced times taken to complete AMS ward rounds and utilisation of in-built AMS functionality, such as automatic antimicrobial stop dates, EMR implementation can support Australian AMS teams to adjust their workflows to focus on these psycho-social factors relating to antimicrobial prescribing.

The core activity of many Australian AMS programs are post-prescription ward rounds [1, 12, 32, 33]. These multidisciplinary rounds comprised of an AMS pharmacist and an ID physician are a highly visible service in Australian hospitals with paper-based medication charts, enabling opportunity for impromptu discussions between clinicians and AMS teams about patients of concern. Some Australian AMS teams anecdotally report reduced AMS team visibility following EMR roll out, with fewer opportunistic AMS consults generated and reduced engagement with treating teams. Verbal communication with prescribers has been shown to increase acceptance rates for AMS interventions, and it is imperative that this strength of AMS rounds is not lost with remote electronic reviews [32, 34].

The main EMRs used in Australia were developed and designed for the American market and developed to maximise hospital billing [3]. These systems have some day-to-day functionality that is adaptable for use in Australia; however, much of the content must be implemented "out of the box", including limited AMS optimisation [2, 3]. A number of AMS-specific third party vendors are available to integrate with EMRs, with varying advantages and disadvantages [4]. Beyond the integration of business intelligence tools with EMR, integration of AMS-specific third party vendors has been limited to date to a small number of Australian hospitals. Development of AMS-specific content during the EMR build is a key limitation. As described by Kuper et al. [4], there is often a heavy reliance on the hospital informatics teams during this time. Depending on the hospital location in Australia, a core state-wide EMR build may be available. The PAH build, for example, has been rolled out across 14 Queensland Health sites to date. Cerner is the primary vendor in New South Wales and has been rolled out to 195 hospitals as at February 2020. There are core state build components, but some local customisation is allowed. Hospitals in other states may be required to take a largely individual approach to meet institutional needs. This heterogeneous approach requires significant personnel and may result in duplication of work. Sharing of such learnings and experiences is essential; however, it must be done in such a way as to minimise any intellectual property concerns. Communication channels are increasing as EMR roll out increases, but were not available at the time of the dashboard development we describe. Innovative AMS initiatives are often omitted from the initial EMR builds and are developed in the years post-go-live. It is the authors' collective opinion that the AMS functions listed in Table 3 are required for Australian initial EMR builds at the time of go-live. This will ensure the ability to benchmark and evaluate AMS programs between individual institutions and at a state and national level.

Table 3 Suggested minimum AMS build features for Australian EMRs

1. Ability to identify patients prescribed antimicrobial therapy
2. Customised antimicrobial order sentences
3. Mandatory documentation of indication
4. Administration prioritisation of intravenous antimicrobial orders
5. Ability to collate microbiology information
6. Ability to record and collect AMS team interventions[a]
7. Ability to generate AMS team referrals[a]
8. Incorporation of local antimicrobial restrictions and approval codes where applicable[a]
9. Ability to identify high risk antimicrobial agents (e.g. vancomycin and aminoglycosides)
10. Clinician alerts for severe allergy mismatch and significant drug interactions

[a] If third party AMS software is not integrated

Opportunities and Future Directions for EMR and AMS in Australia

The scope for further development and enhancement of EMRs to assist AMS efforts in Australia is vast. As more sites implement and roll out electronic systems, increased sharing of AMS-related content and ideas are occurring, with scope to undertake well-planned and strategic research to fully determine the impact of EMRs. Multidisciplinary AMS rounds are a key component of many Australian AMS programs, and EMR implementation provides a platform to expand and explore different models of AMS service delivery. The opportunity exists to leverage EMR data for additional enhancements for the Australian healthcare environment, including bug–drug mismatch screening, sepsis alerts, data mining and artificial intelligence, human factors, and implementation research. There is scope to establish a national electronic AMS focus group to develop comprehensive guidelines for EMR roll out to support our national AMR strategy and existing resources to assist with AMS program development.

CONCLUSION

EMR has a large impact on healthcare workflow, including AMS programs. EMR provides opportunities to overcome specific barriers in practice and facilitates expansion of the reach and coverage of AMS activities. Importantly, by addressing specific barriers to AMS practice, EMR enables AMS teams to focus and impact on more complex aspects of AMS. However, there are several limitations that should be addressed, and we have outlined some lessons learned for other hospitals embarking on digital transformation and point towards future enhancements. The diversity of different EMR software used requires further co-ordination of learnings to complement traditional AMS activities.

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Compliance with Ethics Guidelines. This article is based on previously conducted studies and does not contain any studies with human participants or animals performed by any of the authors.

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