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# Implementation hurdles of an interactive, integrated, point-of-care computerised decision support system for hospital antibiotic prescription

A.L. Chow[a,b,1], A. Ang[c,1], C.Z. Chow[a], T.M. Ng[d], C. Teng[d,e], L.M. Ling[f], B.S. Ang[b,f], D.C. Lye[c,f,*]

[a] Department of Clinical Epidemiology, Institute of Infectious Diseases and Epidemiology, Tan Tock Seng Hospital, Singapore
[b] Lee Kong Chian School of Medicine, Nanyang Technological University, Singapore
[c] Yong Loo Lin School of Medicine, National University of Singapore, Singapore
[d] Department of Pharmacy, Tan Tock Seng Hospital, Singapore
[e] Department of Pharmacy, Faculty of Science, National University of Singapore, Singapore
[f] Department of Infectious Diseases, Institute of Infectious Diseases and Epidemiology, Tan Tock Seng Hospital, Singapore

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ABSTRACT

Antimicrobial stewardship is used to combat antimicrobial resistance. In Singapore, a tertiary hospital has integrated a computerised decision support system, called Antibiotic Resistance Utilisation and Surveillance-Control (ARUSC), into the electronic inpatient prescribing system. ARUSC is launched either by the physician to seek guidance for an infectious disease condition or via auto-trigger when restricted antibiotics are prescribed. This paper describes the implementation of ARUSC over three phases from 1 May 2011 to 30 April 2013, compared factors between ARUSC launches via auto-trigger and for guidance, examined factors associated with acceptance of ARUSC recommendations, and assessed user acceptability. During the study period, a monthly average of 9072 antibiotic prescriptions was made, of which 2370 (26.1%) involved ARUSC launches. Launches via auto-trigger comprised 48.1% of ARUSC launches. In phase 1, 23% of ARUSC launches were completed. This rose to 38% in phase 2, then 87% in phase 3, as escapes from the ARUSC programme were sequentially disabled. Amongst completed launches for guidance, 89% of ARUSC recommendations were accepted versus 40% amongst completed launches via auto-trigger. Amongst ARUSC launches for guidance, being from a medical department [adjusted odds ratio (aOR) = 1.20, 95% confidence interval (CI) 1.04–1.37] and ARUSC launch during on-call (aOR = 1.81, 95% CI 1.61–2.05) were independently associated with acceptance of ARUSC recommendations. Junior physicians found ARUSC useful. Senior physicians found ARUSC reliable but admitted to having preferences for antibiotics that may conflict with ARUSC. Hospital-wide implementation of ARUSC encountered hurdles from physicians. With modifications, the completion rate improved.



## 1. Introduction

Antibiotics are one of the most significant developments in medicine. However, the widespread use of broad-spectrum antibiotics exerts a strong selection pressure for resistance genes in bacteria and promotes the dissemination of such genes [1]. An estimated 50% of all antibiotic use [2] and 20–50% of antibiotic use in empirical therapy was deemed to be inappropriate [3]. Growing antimicrobial resistance has received much attention worldwide [4–6]. Inappropriate antibiotic use drives antibiotic resistance and this limits the range of microbiologically effective antibiotics [7]. Inappropriate antibiotic use in empirical therapy also increases 30-day and in-hospital mortality [8]. Infections involving antimicrobial-resistant organisms result in increased morbidity and hospitalisation, length of hospital stay, all-cause and infection-related mortality, as well as economic losses [9]. In Europe, it was estimated that ca. 25,000 patients died from an infection due to antibiotic-resistant bacteria in 2007 [10]. In the USA, the number of hospitalisations related to antibiotic resistance increased by 359% from 37,000 in 1997 to almost 170,000 in 2006 [11].

* Corresponding author.
*E-mail address:* david_lye@ttsh.com.sg (D.C. Lye).
[1] These two authors contributed equally to this article.

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In response, the World Health Organization (WHO) highlighted this pressing issue with the slogan 'Antimicrobial resistance: no action today, no cure tomorrow' and urged countries to adopt a six-point policy to combat antimicrobial resistance [12]. Major efforts were spearheaded by the US Centers for Disease Control and Prevention (CDC) and the Society for Healthcare Epidemiology of America (SHEA) to encourage the judicious use of antibiotics. Antimicrobial stewardship is one of the key measures proposed by the Infectious Diseases Society of America (IDSA) and SHEA [6,13]. The IDSA/SHEA 2007 guidelines identified formulary restriction and prospective audit with intervention and feedback as key evidence-based strategies for stewardship programmes [14].

Computerised decision support systems (CDSSs) were developed to enhance the effectiveness of antibiotic stewardship programmes in hospitals [15–17]. They provide patient-specific data and antibiotic suggestions to physicians to prescribe the most appropriate antibiotics at the point of care [18,19]. It is suggested that CDSS are more effective when information and advice is generated automatically, within the clinical workflow, and at the time and location of decision-making [20,21]. These systems can educate physicians on the appropriate use of antibiotics, restrict prescription of targeted antibiotics, and review antibiotic prescribing patterns with active feedback to physicians. Patients who receive antibiotics recommended by a CDSS can have better clinical outcomes through their physicians' improved antibiotic prescribing practices [3,15,16,22–24]. Worldwide, only a handful of hospitals have successfully implemented CDSSs for antibiotic stewardship, and few have integrated their CDSS with electronic prescribing [3,15–18,22–26]. We compare our CDSS with others that are similarly applied in an inpatient setting, although a number of these are applied in the intensive care unit whereas our CDSS is used for the entire hospital. The majority of CDSSs provide guidance for definitive treatment of infectious disease conditions where results from microbiology are available [15,22,23]. Some, such as the CDSS used in LDS Hospital in Salt Lake City, UT, [15], also provide guidance for empirical therapy.

In Singapore, antimicrobial stewardship has been acknowledged as a significant part of the fight against antimicrobial resistance [26], with formal guidelines for training and practice proposed since 2012.

In September 2009, Tan Tock Seng Hospital (TTSH) in Singapore established an antibiotic CDSS called Antibiotic Resistance Utilisation and Surveillance-Control (ARUSC), which was integrated into the inpatient electronic prescribing system. ARUSC is an in-house system tailored to the needs of prescribing physicians. Using a rules-based algorithm, ARUSC recommends antibiotic regimens based on guidelines developed by the institutional antimicrobial stewardship committee, taking into account local epidemiology of infections, antimicrobial resistance patterns and evidence-based international guidelines. Inputs from all clinical departments were considered in the development of guidelines, which were endorsed by the hospital's medical board. Inpatient electronic prescriptions of piperacillin/tazobactam (TZP) and carbapenems automatically trigger the launch of ARUSC. In addition, physicians can seek guidance from ARUSC on appropriate antibiotic regimens for an infectious disease condition or for dose adjustment of antibiotics for patients with renal impairment.

The objectives of this paper are: (i) to describe the implementation of ARUSC over three phases from 1 May 2011 through 30 April 2013; (ii) to compare patient and physician factors that resulted in ARUSC launches via auto-trigger with ARUSC launches for guidance; (iii) to examine factors associated with acceptance of ARUSC recommendations in launches for guidance; and (iv) to assess user acceptability through focus group discussions (FGDs) involving junior and senior physicians in the institution.

## 2. Methods

### 2.1. Electronic prescribing and antibiotic CDSS

All inpatient prescriptions made in TTSH are through an electronic inpatient medication record (eIMR) system linked to a patient's electronic records. In January 2009, an antimicrobial stewardship programme was launched to establish and disseminate evidence-based antibiotic guidelines. The CDSS (ARUSC) was integrated into the eIMR in September 2009. Once designed, developed and implemented, it took minimal time to maintain the system. Data were reviewed every 3 months and any necessary changes were discussed within a core team for antimicrobial stewardship. All antibiotics prescribed were captured within both the eIMR and ARUSC database. A separate system linked to the eIMR is used by the pharmacy department for prescribing. After the physician launches the eIMR, he can choose to launch ARUSC via a direct link within the eIMR interface. We will describe this optional launch as one 'for guidance'. Based on the infectious disease condition and patient characteristics that the physician inputs into ARUSC, ARUSC suggests antibiotic regimens for prophylactic, empirical or definitive treatment of infectious disease conditions and provides recommendations for dose adjustment in patients with renal impairment. From April 2011, prescriptions involving TZP and carbapenems result in an automatic and mandatory launch of ARUSC, which we will describe as a launch via 'auto-trigger'.

After ARUSC is launched, it is considered a 'completed launch' when every step within the CDSS is followed through and saved. When a physician closes the CDSS before going through every step, it is a 'prematurely closed launch'. In every ARUSC launch (whether for guidance or via auto-trigger), the physician has to input the infectious disease condition and indicate the antibiotic category (prophylactic, empirical, definitive or renal dose adjustment). ARUSC will retrieve all relevant laboratory data for the patient and will recommend the most appropriate antibiotics based on institutional guidelines. The physician then has the opportunity to compare the ARUSC recommendation with his own choice and can either accept or override ARUSC recommendations (Supplementary Figs S1–9). Acceptance includes every aspect of ARUSC recommendations, i.e. type, dose and duration of antibiotics. This information will flow into the eIMR, where the physician can confirm the prescription.

ARUSC has undergone three major phases since the introduction of auto-trigger in April 2011. This paper covers ARUSC launches from 1 May 2011 through 30 April 2013. Phases 2 and 3 were initiated as a result of physicians' attempts to prematurely close ARUSC with a variety of methods. Modifications to ARUSC were implemented to address these circumventions. Phase 1 was from 1 May 2011 through 11 September 2011. Phase 2 began after the X button in the ARUSC web browser was disabled and lasted from 12 September 2011 through 28 November 2012. Phase 3 started after every shortcut function to close the ARUSC web browser was disabled and lasted from 29 November 2012 through 30 April 2013.

### 2.2. Setting and patient cohort study

TTSH is a 1500-bed tertiary care academic centre that serves the adult medical and surgical population in Singapore. All inpatient electronic prescriptions in TTSH and all ARUSC launches from 1 May 2011 through 30 April 2013 were included in the study. For each prescription, ARUSC recorded the following information: date and time of prescription; patients' demographic information (age and sex); and clinical department managing the patient. If the ARUSC launch was completed, additional information was recorded for each launch: infectious disease condition; launches for guidance;