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Perspective

Opportunities for system level improvement in antibiotic use across the surgical pathway

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SUMMARY

Optimizing antibiotic prescribing across the surgical pathway (before, during, and after surgery) is a key aspect of tackling important drivers of antimicrobial resistance and simultaneously decreasing the burden of infection at the global level. In the UK alone, 10 million patients undergo surgery every year, which is equivalent to 60% of the annual hospital admissions having a surgical intervention. The overwhelming majority of surgical procedures require effectively limited delivery of antibiotic prophylaxis to prevent infections. Evidence from around the world indicates that antibiotics for surgical prophylaxis are administered ineffectively, or are extended for an inappropriate duration of time postoperatively. Ineffective antibiotic prophylaxis can contribute to the development of surgical site infections (SSIs), which represent a significant global burden of disease. The World Health Organization estimates SSI rates of up to 50% in postoperative surgical patients (depending on the type of surgery), with a particular problem in low- and middle-income countries, where SSIs are the most frequently reported healthcare-associated infections. Across European hospitals, SSIs alone comprise 19.6% of all healthcare-acquired infections. Much of the scientific research in infection management in surgery is related to infection prevention and control in the operating room, surgical prophylaxis, and the management of SSIs, with many studies focusing on infection within the 30-day postoperative period. However it is important to note that SSIs represent only one of the many types of infection that can occur postoperatively. This article provides an overview of the surgical pathway and considers infection management and antibiotic prescribing at each step of the pathway. The aim was to identify the implications for research and opportunities for system improvement.

Introduction

Optimizing antibiotic prescribing across the surgical pathway (before, during, and after surgery) is a key aspect of tackling important drivers of antimicrobial resistance (AMR) and simultaneously decreasing the burden of infection at the global level. In the UK alone, 10 million patients undergo surgery every year (The Royal College of Anaesthetists, 2015), which is equivalent to 60% of the annual hospital admissions having a surgical intervention

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(Anon, 2016). The overwhelming majority of surgical procedures require effectively limited delivery of antibiotic prophylaxis to prevent infections (Boucher et al., 2009; Bratzler et al., 2013). Evidence from around the world indicates that antibiotics for surgical prophylaxis are administered ineffectively, or are extended for an inappropriate duration of time postoperatively (Leeds et al., 2016; Tan et al., 2006). Ineffective antibiotic prophylaxis can contribute to the development of surgical site infections (SSIs), which represent a significant global burden of disease. The World Health Organization (WHO) estimates SSI rates of up to 50% in postoperative surgical patients (depending on the type of surgery), with a particular problem in low- and middle-income countries (LMICs), where SSIs are the most frequently reported healthcare-associated infections (HCAIs) (Aveling et al., 2013; Aiken et al., 2013; World Health Organization, 2016). Across European hospitals, SSIs alone comprise 19.6% of all healthcare-acquired infections (Anon, 2013). Much of the scientific research in infection management in surgery is related to infection prevention and control in the operating room (Birgand et al., 2014; Cosgrove, 2015; Allo and Tedesco, 2005), surgical prophylaxis (Bratzler et al., 2013; Cusini et al., 2010; Davey et al., 2013), and the management of SSIs (Gaynes et al., 2001; Bergs et al., 2014), with many studies focusing on infection within the 30-day postoperative period (World Health Organization, 2016; Løwer et al., 2013). However it is important to note that SSIs represent only one of the many types of infection that can occur postoperatively.

This article provides an overview of the surgical pathway and considers infection management and antibiotic prescribing at each step of the pathway. The aim was to identify the implications for research and opportunities for system improvement.

Infection management in surgery

To date, research on surgical antibiotic prescribing has focused on the preoperative period and has largely been confined to prophylaxis, hospital inpatients, and SSIs. The WHO has recently published guidelines for the prevention of SSIs (World Health Organization, 2016). The guidelines provide detailed and evidence-based recommendations for the prevention of SSIs, including surgical antibiotic prophylaxis. The guidelines reinforce the recommendation against prolongation of surgical antibiotic prophylaxis beyond the surgical procedure as a means to prevent SSIs. In addition, they recommend worldwide surveillance of SSIs as a key component of any infection prevention and control programme. However, they do reflect that SSI surveillance is commonly poorly performed, with inconsistencies in practice, including in the type, duration, and quality of the surveillance (Table 1).

Beyond SSIs, there remains little research on the broader management of postoperative HCAIs. In order to significantly mitigate against the drivers of AMR and simultaneously reduce infection rates, it is critical to optimize antibiotic use before, during, *and after* surgery, and to look at care settings beyond the hospital – where most patients originate from and return to. Many factors impact the risk of subsequent infection in a person who undergoes surgery; the patient's baseline health and wellbeing, patient's comorbidities, the healthcare professionals involved, and how these professionals work as a team can all influence infection-related surgical outcomes (Undre et al., 2006; Hull et al., 2011). The management of the patient in the immediate postoperative period is critical, as is their hospital length of stay. The risk of acquiring an HCAI, e.g. hospital-acquired pneumonia (Garibaldi et al., 1981; Conde and Lawrence, 2008), device-related bacteraemia, or *Clostridium difficile*-associated diarrhoea, is high in the surgical patient (Krapohl et al., 2013) (Table 2). The use of invasive devices such as intravenous lines, urinary catheters, and mechanical ventilation increases the risk of postoperative infection. In addition to this, the use of neuromuscular blocking agents during surgery to aid anaesthesia, together with reduced mobility in the immediate postoperative period, increases the risk of pneumonia (Bulka et al., 2016; Sachdev and Napolitano, 2012), which carries an estimated mortality of between 10% and 18%, even with appropriate antibiotic treatment (Croce, 2000).

Antibiotic prescribing in surgery—culture and context

The surgical pathway has many actors, steps, and actions specifically related to the management of infection and antibiotic use. Nurses, surgeons, anaesthetists, pharmacists, and allied healthcare professionals in the pre-assessment clinic, in the operating room, on the ward, and in the community during postoperative follow-up, all contribute to the care of the surgical patient. Within this complex pathway, the responsibility for the management of infection remains poorly defined at each step. In the operating room, it is unclear whether it is the anaesthetist or the operating surgeon who should assume responsibility for the timing, choice, and dose (or the need for a second dose) of the prophylactic antibiotic (Grocott and Pearse, 2012; Parker et al., 2000) (Table 1).

In the past few years, surgery has turned to aviation-inspired checklists to improve the reliability of the processes of care, and subsequently their outcomes. A number of checklists have been published and evaluated in some detail, with the best known one perhaps being the checklist developed by the WHO (Haynes et al., 2009). These checklists have identified antibiotic prophylaxis to be one of the objectives for safe surgery (World Health Organization, 2008). In the checklist, the requirement is that in the presence of the nurse, anaesthetist, and surgeon, the 'surgical team' confirm that antibiotic prophylaxis, where appropriate, is administered within 60 min of incision. However, the boundaries of responsibility for surgical antibiotic prophylaxis are not clear, specifically whose responsibility it is to decide what antibiotic prophylaxis is given and at what time (Tan et al., 2006). This is reported to be due in part to the culture and hierarchies that influence the behaviour of staff in the operating room, and also to the workflow and the environment of the operating room, which can act as obstacles to appropriate surgical antibiotic prophylaxis (Tan et al., 2006).

The lack of clarity around responsibility for antibiotic prescribing carries over into the postoperative period (Charani et al., 2017a). The responsibility for antibiotic prescribing in surgical teams is dispersed and the optimization of antibiotic therapy is often not prioritized. This leads to inappropriate antibiotic use with a prolonged duration (Leeds et al., 2016) (Table 1). This prevalent culture surrounding antibiotic decision-making in surgery needs to be understood and the expectation of surgical teams in relation to stewardship should be adjusted in view of this culture. Interventions in surgery should target the specific behaviour determinants and they should be developed in closer collaboration with surgical leaders.

Historically, most antibiotic stewardship programmes have been focused on medical specialties (Davey et al., 2013; Davey et al., 2017; Charani et al., 2017b). Within surgery, the 'low hanging fruit' is surgical antibiotic prophylaxis, with the majority of stewardship interventions targeting this single step (World Health Organization, 2016; Davey et al., 2013). Enhanced recovery after surgery (ERAS) programmes are now in place in many hospitals worldwide, and a recent systematic review has demonstrated that implementing such programmes can reduce HCAIs (Grant et al., 2017).The ERAS protocols include recommendations for surgical antibiotic prophylaxis, but focus more on the entire perioperative plan for patients to promote rapid recovery and discharge postoperatively (Lassen et al., 2009). Engagement with and

Table 1
Gaps in the surgical pathway and opportunities for system change that will impact infection management and antibiotic prescribing.

	The surgical pathway		
	Perioperative period	Postoperative period	Follow-up care (primary/social/home) and surveillance
Gaps in practice that potentially impact infection management and antibiotic prescribing	Lack of clarity on whose responsibility it is to decide on the choice, dose, and timing of antibiotic prophylaxis	Gaps in the diagnosis and management of hospital-acquired infections in the postoperative patient	Follow-up care:
	Lack of clear understanding of the influence of culture and team dynamics (Tschan et al., 2015) on the implementation of the surgical checklists, e.g., WHO checklist	Lack of leadership in antibiotic decision-making	Community follow-up of care in the postoperative period to ensure patient recovery
	Operating room design issues, e.g., thoroughfare, airflow disruption, or poor temperature control, or poorly designed surfaces	Lack of knowledge on the influence of culture and team dynamics on antibiotic prescribing decisions in surgery	Surveillance:
	LMIC-specific: lack of equipment to avoid infection, lack of access to antibiotics	LMIC-specific: lack of access to antibiotics	Lack of consistency in the method of SSI surveillance, e.g.: Duration of surveillance Type of surveillance Quality of surveillance Feedback to surgical teams
Impact on clinical processes and patient outcomes	Inappropriate antibiotic prophylaxis resulting in increased risk of SSIs	Inappropriate management of hospital-acquired infections in the postoperative patient, including prolonged duration of antibiotic therapy	No system for linking SSI outcomes to antibiotic prescribing behaviours before, during, and after surgery
	Ineffective environmental precautions to prevent HCAIs	Lack of postoperative critical care training leading to over-diagnosis of sepsis in the postoperative period	Lack of adherence to SSI programmes
Opportunities for change	Simple solutions such as:	Provision of education and training at post-graduate level	Developing a co-ordinated package of follow-up care in the community
	Clarity on roles and responsibilities for antibiotic prophylaxis in the operating room	Provision of national and local guidelines for antibiotic prescribing in surgery	Building on existing surveillance and developing new surveillance systems using a pragmatic approach, e.g., National Surgical Quality Improvement Programme (USA) or using mobile phone-based surveillance (LMIC)
	Monitoring operating room traffic and airflow to improve the operating room environment and prevent infections	Inclusion of and engagement with surgical teams in antibiotic stewardship interventions	
	Organizational support and leadership in implementing the changes	Developing better routes of access to antibiotics	
		A greater understanding of the influence of culture and context on antibiotic prescribing behaviours	
		Development of context-specific antimicrobial stewardship interventions	
Across the entire pathway	Lack of engagement with, and involvement of, the surgical teams in antibiotic prescribing interventions, together with a lack of knowledge on the optimization of antibiotic use in surgery (Charani et al., 2017a) Opportunity for change: Defining a role for antimicrobial stewardship within the surgical team, and developing targeted antibiotic prescribing interventions in surgery		

WHO, World Health Organization; LMIC, low- and middle-income countries; SSI, surgical site infection; HCAI, healthcare-associated infection.

inclusion of the surgical teams and surgical champions in the development of antimicrobial stewardship programmes is the first step in bringing about better outcomes. Organizations and national bodies can support this through legislation and policies that promote and endorse better antibiotic prescribing across the whole surgical pathway.

Although surgical checklists are generally shown to have beneficial effects in reducing surgical infections (Treadwell et al.,

Table 2
The incidence of the most commonly occurring healthcare-associated infections in postoperative patients.

Type of hospital-acquired infection	Incidence range (as a percentage of postoperative patients) reported in the literature[a]
Hospital-acquired pneumonia	2.5% (Conde and Lawrence, 2008) to 17.5% (Garibaldi et al., 1981)
Surgical site infections	1% to 9.8% (England PH, 2016)
Urinary tract infections	2% (Chan et al., 2013) to 10% (Stéphan et al., 2006)
Clostridium difficile-associated diarrhoea	0.28% to 7.2% (Masgala et al., 2012; Flagg et al., 2014)

[a] Depends on the type of surgery and patient population; figures are from the published literature.

2014) – though not always SSIs (Haugen et al., 2015) – overall, they have had a mixed reception (Aveling et al., 2013; Haynes et al., 2009; Russ et al., 2015). In India, for example, despite improvements in the use of the surgical site safety checklist, translation of its use in terms of patient safety outcomes has not been measured to understand the differences made in reducing SSIs, morbidity, and mortality (Patel et al., 2015). Historically, LMICs have suboptimal investment in surgical services, and existing surgical systems are growing too slowly to meet the increasing demand (Ng-Kamstra et al., 2016). The success of interventions such as the WHO checklist targeting surgical safety are highly context-dependent and variable, and are influenced by economic, cultural, and social factors, including role identity and hierarchies within healthcare teams (Aveling et al., 2013). In particular, LMIC hierarchies have a significantly greater impact on the successful adoption of interventions in surgery (Aveling et al., 2013). Importantly, leadership, flexibility, and teamwork are required for the implementation of checklists to be effective in any setting (Walker et al., 2012; Gillespie and Marshall, 2015). This lesson applies to the successful implementation of any patient safety initiative, including interventions aiming to optimize antibiotic use (Undre et al., 2006; Dixon-Woods et al., 2013).

In particular for antibiotic prescribing, studies have described the influence of cultural determinants on prescribing outcomes (Charani et al., 2013). Antibiotic prescribing is a social act, influenced by the perceived need for clinical autonomy of individual prescribers and the existing hierarchies within teams (Charani et al., 2013). Changing antibiotic prescribing behaviours, with a view to optimizing patient-related infection outcomes, cannot be done in isolation simply by providing guidelines and policies. Existing guidelines and frameworks do not consider the variance in resources and infrastructure within LMICs (World Health Organization, 2016). In LMICs, inconsistencies in available surgical capability and resources is far more pronounced between rural and urban settings and between different LMIC countries, than it is in high-income countries where the minimum standard of care is provided in any setting. Research from different LMIC settings is lacking and is urgently needed to develop contextually sound and driven interventions that are sustainable.

The culture within specialties, organizations, and countries has the power to influence the outcome of interventions (Hofstede, 2011; Buzan, 2010; Al-Bannay et al., 2013). Culture refers to how individuals, as members of a team, learn and share knowledge in order to generate behaviours (Spradley, 1980). Culture is learned, and in order to influence practice, it needs to be studied. The culture of treatment of infection and antibiotic use in the surgical specialty has distinct features in contrast to acute medicine, because the dynamic of decision-making in the patient surgical pathway is different, as are the causal factors that influence patient-related outcomes. Understanding the contextual and cultural determinants of infection management and antibiotic prescribing in surgery is critical to the development of context-specific interventions that incorporate the need for flexibility, local leadership, and teamwork.

In an extensive review of the implementation of the Matching Michigan intervention for the prevention of blood stream infections by intensive care units in the UK (Dixon-Woods et al., 2013), the researchers reported that local culture was 'highly consequential' to the intervention outcome. Furthermore, the most successful units were reported to be those that had adapted the intervention to the local context and used local champions to drive and implement it. In surgery, one key step would be better engagement with the surgical leaders and the inclusion of surgeons in antimicrobial stewardship programmes. With the increasing threat of AMR, there is an urgent need to understand how to minimize the burden of infection and optimize antibiotic use across the whole surgical pathway. Addressing the gaps in the surgical pathway will reduce the total antibiotic use and significantly mitigate drivers for AMR and the burden of infection (Table 1). Decision-making within multidisciplinary surgical teams and communication with professionals across organizational boundaries in LMICs remain unexplored. Resource limitations mean that fewer actors are involved in the surgical pathway, but there are also opportunities for innovative team composition. In the global context it is essential to redefine the antibiotic stewardship roles of the entire healthcare team across conventional organizational and professional boundaries. In addition, in LMICs the role of antibiotic stewardship in surgical care pathways is imminent, since the inappropriate use of antibiotic surgical prophylaxis has led to an increase in SSIs (Rana et al., 2013). The need for research on this topic in LMICs is particularly important to bring about efficiencies at the organizational level and to address the huge impact on out-of-pocket health expenditures and loss of earnings through prolonged postoperative recovery for the most vulnerable in society.

The way forward

Interventions in antibiotic use tend to consider and address only *one* point at a time on the patient pathway, and in the case of surgical patients, attention has been focused primarily on prophylactic antibiotic use. And yet multiple interventions have the potential to influence infection-related outcomes in the surgical patient. Social science perspectives to understand the structural, cultural contextual determinants of antibiotic use in surgery need exploring, with the potential to inform sustainable quality improvement and surgical safety initiatives. Identifying and mapping current actors and actions in the surgical specialty in different healthcare settings will inform interventions that are context-specific and relevant to the local patient population. They will also help ensure greater equity in access to safe surgery on a global scale.

Addressing antibiotic prescribing and AMR across sectors and cultures will enable surgical healthcare professionals to mobilize and drive organizational, national, and global change. Engaging with and involving surgeons and anaesthetists in the antibiotic stewardship agenda is essential, especially as it will enable the investigation of a critically unexplored domain in healthcare on a global scale, and optimize interventions within and beyond healthcare environments that have been entrenched in hierarchies and cultural norms. Addressing the gap of infection management in the surgical pathway will also impact on international policy and practice in antibiotic resistance and stewardship. Addressing the factors that influence AMR across the surgical pathway in resource-limited environments has the potential to profoundly impact the health outcomes of the millions of people who undergo surgery each year.

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Conflict of interest

Charani, Tarrant, Ahmad, Birgand, Mendelson, Leather, Singh, Moonesinghe and Holmes have none to declare. Sevdalis is the Director of London Safety and Training Solutions Ltd, which provides team skills training and advice on a consultancy basis in hospitals and training programmes in the UK and internationally.

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