Short Communication

From farm to fork: global surveillance trends of animal-food-human antimicrobial resistance

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Abstract

Objectives: Global surveillance measures keep trending with antimicrobial resistance (AMR) from farm to the final consumer. It is intended to review these trends within the past few decades.

Materials and Methods: This short communication showcases AMR surveillance basics, methods, processes, technicalities and milestones within recent decades in relationship to AMR emergence from farm to fork.

Results and Conclusions: Antibiotics and antimicrobial agents contribute to AMR dynamics. Passive and active AMR surveillance strategies continuously render data-driven robust systems for monitoring resistance levels and thereof changes across all geographical regions.

Key words: antimicrobial resistance; antibiotics; farm-to-fork; surveillance.
in food can be brought about by: 1. food contamination with AMR bacteria and AMR genes as well as 2. intentional addition of microorganisms (with AMR properties) to food as auxiliary technical substance (Verraes et al., 2013).

Events leading to development of resistance in bacterial life include chromosomal mutations, plasmid-based mutations, and acquisition of genes. Besides, the most studied location of resistance emergence is the digestive tract of human and animals. Basically, foodborne pathogens that bring about diarrheal diseases include Salmonella spp., Campylobacter spp., Escherichia coli, Yersinia spp., Clostridia spp., and Listeria spp. (Acar and Rostel, 2001). Notwithstanding that antibiotics critically help in reducing the burden of communicable diseases, AMR still threatens the effectiveness/efficacy of successful infection treatments (Ndihokubwayo et al., 2013). With respect to food processing domains, the use of antibiotics potentially at some point, lead to bacterial resistance and once developed, would not be bound to borders of different countries (Acar and Rostel, 2001). Indeed, the use of antibiotics in primary agricultural production remains very vital to AMR selection in bacteria, the latter that subsequently finds its way into foodstuffs. Nonetheless, the transfer of AMR (in food processing environment) can happen via influence of food processing/preservation techniques, influence of biofilms, cross-resistance to antibiotics, and chemical biocides (Verraes et al., 2013).

Although antimicrobial agents have always driven the development of AMR (Felmingham, 2002), how resistance in bacteria develops would on the other hand depend on the character of resistant gene(s) as well as characteristics of exposed bacterial populations (Franklin et al., 2001). A growing threat to effective treatment of an ever-increasing range of infections caused by bacteria, parasites, viruses, and fungi, AMR remains a complex global public health challenge/crisis that threatens the return of untreatable infections on a massive scale with no single strategy to fully contain the emergence/spread of infectious organisms that have attained resistance. The development and implementation of effective strategies to curtail the emergence and spread of AMR is imperative, which via evaluating effects of interventions would cumulatively depend on collecting accurate/representative information that describes the degree/extent of the problem (Silbergeld et al. 2008; WHO, 2014). Indeed, the USA has demonstrated how critical AMR is by extending collaborative/cooperative relations with the EU in a bid to strategically curb AMR emanating from food products (The PCAST, 2014). More so, the global and regional movement of food/food products calls for robust susceptibility testing and accurate monitoring of any emerging AMR cases (Donaghy et al., 2019). The international spread of AMR microorganisms therefore suggests such resistance to be of a global scale that requires a common, unified, and united strategy (Monnet, 2000) and this is where surveillance in the microbial context plays a very vital function/role.

Surveillance according to Office of International des Epizootes (OIE) refers to the continuous investigation of given population to detect the occurrence of disease for control purposes, which may involve testing of a part of the (given) population (Franklin et al., 2001). With respect to AMR, surveillance is a systematic, on-going data collection, analysis, and reporting process that quantitatively monitors temporal trends in the distribution and occurrence of resistance and susceptibility to antimicrobial agents, providing useful information that guides disease control (and medical practice) activities (Cornaglia et al., 2004). Surveillance, whether passive (samples submitted to laboratory for testing by sources outside the programme) or active (programme-developed sampling scheme based on objectives of programme and actively obtained isolates), has the primary purpose to generate data, which can involve such facets like: 1. risk analysis to determine risk to human/animal health; 2. detecting emerging AMR; 3. determining trend in prevalence of reduced susceptibility to certain antimicrobial (or resistance) in defined population; 4. providing basis for policy recommendations for animal/public health; 5. generating data to guide the design of further studies; 6. identifying with the need for potential interventions; and 7. providing information for prescribing practices and prudent use of recommendations (Franklin et al., 2001). Considerations for surveillance would include: 1. monitoring of bacteria from animal-derived food collected at different steps of food chain, including packaging, processing, and retailing; 2. the basic exposure mechanisms of humans to resistant bacteria from food would not (necessarily) differ across countries; and 3. exposure of humans to resistant bacteria can be either direct (through exposure to zoonotic pathogens, e.g. Campylobacter spp., Salmonella spp.) or indirect (through exposure to resistant genes potentially transferable from commensal animal bacteria) (Franklin et al., 2001).

Technically speaking, well-known surveillance methods include culture-based procedures, main phenotypic methods (test-tube, microtitre plate, and congo red agar), Confocal Laser Scanning Microscopy (CLSM), quantitative polymerase chain reaction (qPCR), Pulse-Field Gel Electrophoresis (PFGE), Multi-Locus Sequence Typing (MLST), and Whole/Partial Microbial Genomic Sequencing. The latter, according to Stärk et al. (2019), is among the newer surveillance methods considered more robust with merits such as rapid dissemination of results, high resolution, accuracy, and precision, except with some demerits such as high (initial) cost, complexity of bioinformatic processing, and its non-standardized quality assurance. On the other hand, ‘omics’-based approach, e.g. genome metabolic, can help us to improve AMR detection in foods. The likes of metatranscriptomics, proteomics, and metabolomics (Caniča et al., 2019) can form an integral part of next generation sequencing (NGS) capable of monitoring environmental hygiene of newly produced foods and detecting any new antibiotic resistant organism.

Although AMR surveillance systems serve as a source of multi-centric antimicrobial susceptibility data, an already existing database—a merit especially with respect to clinical microbiology laboratories (Monnet, 2000), they fundamentally help in determining the level of resistance in specific geographical regions, as well as monitoring changes in levels of resistance. Besides, the information provided about mechanisms of resistance, how such resistance develops, persists within a given population, and then spreads to other populations are very vital, all of which are critical for developing/monitoring intervention programmes that would help minimize resistance spread (Felmingham, 2002). Yet, carrying out AMR surveillance and at regular intervals to monitor prevalence changes of resistance bacteria of food origin remains a very critical aspect of strategy that helps us to limit (AMR) spread (Franklin et al., 2001). Nonetheless, surveillance of resistance trends would continue to focus on such different targets as: 1. evolving trends in antibiotic resistance; 2. evolving trends in the incidence of particular mechanisms of resistance; 3. evolving trends in the incidence of particular resistant clones; and 4. evolving trends in the incidence of AMR infections (Cornaglia et al., 2004). Some challenges that confront AMR surveillance can include: 1. lack of standardization of method used, the antimicrobial tested, and differences in quality of susceptibility testing results; 2. possible differences in frequency and distribution of sampling among countries/regions; 3. absence of consensus on minimum set of data to be collected; 4. standardization of databases and level of stratification of reports; and 5. the presence of several (proposed) measurement units to show level of AMR, yet no consensus on which one should be applied/used (Monnet, 2000). Meanwhile, the pertinence of on-site food safety surveillance against AMR led to the
Most of these AMR surveillance advancements have evolved within the past three to four decades. Importantly, some key global milestones of AMR surveillance associated with animal, food, and human within the past decades are shown in Figure 1. Historically, interest to monitor AMR actually began about the mid-1960s. By late 1970s, some form of surveillance of resistant bacteria in human infections had begun in some countries like USA, UK, France, South Africa, Australia, Thailand, and Venezuela (Acar and Moulin, 2013). By the 1990s, World Health Organization of the United Nations (WHO) called on concerned sectors to work together to eliminate the burden of AMR arising from the use of antimicrobials in food producing animals (Aidara-Kane, 2012). Given that sampling of retail foods was forming part of integrated monitoring of foodborne AMR bacteria, by 1996, the National Antimicrobial Resistance Monitoring System (NARMS) got established in the USA (Acar and Moulin, 2013). By 1998, the World Health Assembly in the view to encourage rational/reduced use of antimicrobial agents in animal food production adopted resolution WHA51.17 on AMR. By 2000 in Geneva, the WHO established the ‘Global principles for the containment of antimicrobial resistance in animals intended for food’ which allowed for expert consultations jointly with Food and Agriculture Organization of the United Nations (FAO) and World Organization for Animal Health (OIE), clearly demonstrating the select for AMR bacteria is required within antimicrobial use in food animals and their resistance determinants are transferrable to humans via the food chain (Aidara-Kane, 2012). By 2001, the Office International des Epizooties (OIE) 69th General Session adopted the resolution No. XXVI, which would enable OIE Specialist Commissions develop international standards within the AMR domains. Member countries were encouraged to embrace new methodologies that would establish objective/science-based contaminant of AMR in animal bacteria (Acar and Röstel, 2001).

Fast forward to 2008, the WHO Advising Group on Integrated Surveillance of Antimicrobial Resistance (WHO-AGISAR) was established to minimize public health impact of AMR associated with the use of antimicrobial agents in food animals. The WHO-AGISAR comprised of over 20 internationally renowned experts in disciplines broadly relevant to AMR (Aidara-Kane, 2012) that have regularly convened, started with its 1st meeting 15–19 June 2009 in Copenhagen-Denmark, 2nd meeting 5–7 June 2010 in Guelph-Canada, 3rd meeting 14–17 June 2011 in Oslo—Norway, 4th meeting 24–25 June 2012 in Aix-en-Provence—France, 5th meeting 3–5 September 2013 in Bogota—Columbia, 6th meeting 10–12 June 2015 in Seoul—Republic of Korea, and 7th meeting 17–20 October 2016 in Raleigh—NC (WHO, Food Safety webpage, accessed 24 August 2019). Besides, the WHO has led some regional surveillance efforts of AMR, especially within the present decade. Not long ago, WHO Regional Office for Africa (AFRO) published a guide to facilitate establishment of laboratory-based surveillance for priority bacterial diseases. Besides, whilst health ministers of WHO South East Asia Region have met (2011), to articulate (their) commitment...
to combat AMR, the WHO Western Pacific Region is believed to be growing in this process. On the other hand, ReLAVRA—the Latin American Antimicrobial Resistance Surveillance Network has increased their ability to detect, monitor, and manage antibacterial resistance (ABR) data. Mindful of public threats posed by current trends in AMR, the Eastern Mediterranean Regional Committee in 2013, adopted resolutions addressing AMR. In addition, Foodborne and Waterborne Diseases and Zoonoses Network FWD-Net—a European network coordinated by European Centre for Disease Prevention and Control (ECDC), helps us to collect foodborne bacteria data, jointly with European Food Safety Authority (EFSA), on AMR in indicator/zoonotic bacteria as it affects animals, foodstuff, as well as human (WHO, 2014). In the UK, interestingly, surveillance measures have been people-oriented, an AMR strategy launched in 2013 that focuses on public-private sector volunteering (HM Government, 2017; RUMA, 2017), which between 2013 and 2016 substantially reduced antimicrobial use in broilers and pigs by 21% (Davies and Wales, 2019). Largely in Europe as well, data about surveillance and control schemes of foodborne AMR have become increasingly available, which buttresses the emphasis on reducing the use of antimicrobials (DANMAP, 2017).

Conflict of Interest Statement

None declared.

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