From white coat and gumboots to virtual reality and digitalisation: where is veterinary medicine now?

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Abstract. The paper reviews the current role of information and communication technologies in veterinary medicine, management of animal health, animal production and food safety worldwide and discusses the shift from recognising the digital revolution as a novelty to accepting it as a norm. Due to the diversity in veterinary medicine, it is unlikely that information and communication technologies will fully substitute the need for field veterinarians in direct contact with animals, farms, diseases, food production and food products. However, information and communication technology has a growing role in our work and provides opportunities to exploit new technologies for professional and societal affirmation. Consumers, trade and regulations drive demands on veterinary medicine, reflected in our increased focus on prevention and early recognition of animal diseases and food safety issues through output-based and integrated monitoring systems and shared responsibility between public and private sectors. Simultaneously, information and communication technology has been incorporated within these demands and so now has roles in: veterinary clinical practice, heard health management, animal health databases, traceability of animals and their products, trade and veterinary certification, animal disease data analysis, tools for veterinary education and animal health diagnostics. The symbiosis of bio- and information technology has opened a new era in health and food production, providing a novel chance for veterinarians to make a significant leap in their professional development, achievable only through strategic and active participation as leaders and collaborators.

1. Global convergence through informatization

During the 1970s, a decade when the first email was sent, SONY launched its Walkman and the digital camera was introduced, the German philosopher Martin Heidegger stated: “Everywhere we remain unfree and chained to technology, whether we passionately affirm or deny it.” The continuing convergence of telecommunications, computers and digitisation has left nations – big or small – with little option but to informatize so they can effectively exist and compete in the world’s economy [1]. Information and communication technologies (ICT) have now completely changed operations for example, in the banking and tourism sectors, evident if we just compare how we manage our personal banking and book travel or accommodation now and just a few decades ago. ICT has not just influenced business and economic aspects, but also societal aspects, with new tools for communication (social networks) and the increased availability of information in the contexts of democracy, globalisation, human rights and social responsibility issues.

As animal health, welfare and food safety professionals we can readily acknowledge consumers, trade and regulations drive the changes in our everyday work. Today, we are more specialised and versatile in the tasks we do, more output driven, more publicly responsible regarding the approaches and tools we use and more conditioned by scientific and cost-effective justification for our decisions. Our professionally specific challenges are already interlinked with the ICT framework of our modern
society and economy, and the question arises, are we open to recognise and (pro)actively react to the possible threats, opportunities and novel roles these technologies offer?

This paper reviews the role of ICT in current operations within veterinary medicine, management of animal health, animal production and food safety worldwide and discusses the shift from recognising the digital revolution as a novelty to accepting it as a norm.

1.1. Informatization and veterinary medicine, animal health and production and food safety

It is easy, from today’s perspective, to recognise the importance, developments and roles of veterinary medicine in the agricultural age or even the industrial age. The period when agriculture was the predominant factor shaping societies, governance, economies and life (agricultural age) ended by 1750 with the agricultural revolution during the 18th and early 19th centuries that introduced industrialised food production through the technological improvements brought about in the industrial age. During the industrial age, veterinary medicine made a huge leap forwards by rebranding itself from a vocation to a profession (marked by founding the first veterinary school in Lyon in 1762) and constantly expanding its subject matter (from only horses to cattle and other livestock, followed by companion animals, aquatic animals, insects as a source of food, wildlife, zoonotic agents, environmental health, integrated and interdisciplinary chains of food production and control, veterinary public health) [2]. From the 1950s, the information age (also called the digital age) has rapidly changed definitions of jobs, work, work organisation and hierarchy and the skills currently recognised as “must have” to be competent and successful. Veterinary medicine, in addition to requirements for expanding veterinary professional competencies, faces the demand to use more both “soft” skills (such as communication, leadership, team work) and competencies from non-medical disciplines (management, governance, ICT, regulatory framework etc.). For sectors such as financing or transportation, with structured systems of operations, predefined variation of mostly mechanistic inputs and influences, and globally harmonised procedures, it is far simpler to integrate ICT. In contrast, the food production and animal health sectors include many animal species and types of production, unfolding in a variety of production systems (i.e. traditional, extensive, and intensive), market economy frameworks (free, centralised or mixed), socio-economic environment (western democracy, post-socialist transitional, developing etc.) all coupled with more complex and diverse biological risks resulting from globalisation, urbanisation and climate change [3]. It cannot be expected that ICT including artificial intelligence (AI) will replace field veterinarians or provide universally applicable tools for all operational aspects of our sector, notwithstanding ICT’s already growing role in our work and the opportunities it affords to exploit new technologies for our professional and societal affirmation [4].

2. Drivers of changes in veterinary operations

Widening horizons during the second half of the last century in terms of globalisation and international trade had a spill-over effect on animal production and health worldwide, embodied in the Sanitary and Phytosanitary Agreement (SPS) of the World Trade Organisation [5]. Key provisions of the SPS (transparency, harmonisation, risk analysis, equivalence, regionalisation) and strengthening roles of international organisations in standard setting (OIE – World Organisation for Animal Health, IPPC – International Plan Protection Convention and Codex Alimentarius) shaped major changes in the perspective and operation of animal health management and food safety on both national and global levels. These changes are reflected in the development of output-based animal health policies focused on prevention and biosecurity, food safety monitoring throughout the supply chain including pre-harvest, and redistribution of responsibility and financing between public and private sectors.

2.1. Risk mitigation; biosecurity rather than control/containment

The purpose of animal health control programs and measures has changed from counting cases and outbreaks and ensuring decreasing trends of disease incidence to demonstrating and maintaining “freedom of disease” at country, industry or farm levels, achieved by active surveillance and biosecurity. According to the European Union (EU) animal health law (2016), biosecurity is one of the
key prevention tools at the disposal of producers and others stakeholders for preventing introduction, development and spread of transmissible animal diseases to, from and within an animal population [6]. Risk assessment, once reserved for assessing disease risk at country and/or regional levels for the purpose of international trade, has become pivotal for effective farm biosecurity, while biosecurity plan implementation and maintenance relies on cost effectiveness (i.e. recognised financial justification by farmer/establishment for disease prevention measures).

Country borders are another location for implementing biosecurity in order to prevent disease introduction. Improving border biosecurity without major disturbances to the movement of people or goods is an on-going challenge, since these movements are one of the major factors promoting economic development, cohesion and market competitiveness.

2.2. Integrated food safety/quality control systems
Sanitary supervision of food on the retail market under jurisdiction of veterinary or public health administration (i.e. inspection) proved to be costly and inefficient as trade and movement of animals and products increased and was liberated. Following food-borne incidents in the United States during 1970s (broken glass found in dry baby food, death and illness due to Clostridium botulinum) and the bovine spongiform encephalopathy (BSE) crisis in 1990s in Europe, the need was recognised “to re-establish public confidence in food supply, food science, food laws and food controls” [7]. Integrated food safety and quality control systems have been developed to ensure high levels of public health and food safety, on the level of both individual producers (i.e. GMP – Good Manufacture Practice, GAP – Good Agricultural Practices and HACCP – Hazard Analysis and Critical Control Points) and countries (i.e. “farm to table policy” of the EU). In formulating the “farm to table policy”, the European Commission (EC) wanted to promote defined roles and responsibilities of stakeholders, traceability, transparency, risk analysis and risk management.

Documentation and traceability not only enable reduction of food-borne disease incidents but also aid outbreak investigation. These achievements further support prevention and control measures through identifying critical control points to reduce contamination (hazard and risk analysis). However both traceability and risk analysis work only if quality, consistent and real-time data from veterinary surveillance are available.

2.3. Increasing responsibility and initiative of the private sector
Public policies in developed countries are made with consideration of the interests and participation of those groups who will take part in their implementation and who will carry both burden and benefits of their effects. Such policies have shown to be more accepted, feasible and effective, bringing with shared governance also shared responsibility and distribution of costs among stakeholders. Thus, stakeholders responsible for designing and implementing animal disease surveillance and food safety programs are national and international veterinary authorities, livestock and food/feed industries and farmers’ associations. Farmers are considered responsible for having and consistently implementing biosecurity measures on farms, and food industries and producers are accountable for implementing in-house quality control systems (i.e. HACCP), while the public sector still has a role in promoting, harmonising and optimising health and food safety standards and requirements. Maintaining these partnerships faces challenges of continuously reducing public funding on one hand and on the other, the needs of business for a stable operating environment and reliably foreseen revenues. These business needs are in contrast to the continuous and accelerating surge of new biological and chemical risks and consumers’ demands for rigorous controls.

3. Some examples of addressing the demands of drivers by using ICT
Considering the above-mentioned major drivers of change in veterinary operations worldwide, ICT has already been recognised as providing solutions and has found even wider roles in veterinary medicine. Currently used ICT tools and applications can be categorised according to their purposes as follows:
3.1. Veterinary clinical practice tools
Veterinary practice management tools available as commercial software incorporate patient and/or practice management. They can be cloud- or web-based and generally include electronic health records, billing and financial analysis. Some tools also accommodate clients with options for on-line (web or smart phone) appointment scheduling, insight into courses of treatment and follow up. Compared to early tools, today, they even incorporate options for electronic clinical audit (quality control protocol) and monitoring antimicrobial usage. Comparably to human medical research, electronic animal patient records are even used for population surveys [8].

In addition to digital and computerised diagnostic equipment commonly used in veterinary practices (i.e. haematology analysers, digital imaging diagnostics), smartphone apps are now available to transform phones into a clinical-quality, single-lead electro-cardiograph (ECG) recorder (partnered with an ECG monitor) [9]. Technological advances and the increased availability of 3D-printing is used in producing 3D models representing patient’s anatomy very accurately and applicable in planning surgery, radiotherapy, customised prosthetics and veterinary education. Additionally, bio-printing, the printing of live cells and tissues to be implanted without any autoimmune reaction, is currently an active field of research [10].

3.2. Herd health management tools
Information management systems for health and production of farm animals were developed in the 80s to support farm management, prevent disease introduction, ensure product quality and optimise output:input ratio and farm development [11]. These tools started with recognition of the need for farm data collection and analysis, due to their potential to improve feeding, disease and reproduction management efficacy. These tools assist both farmers and veterinarians in decision making processes.

Coupled with computerised herd health management, biosensors and biosensing methodologies are now in use for the specific measurement of individual and multiple parameters covering an animal’s physiology as well as monitoring of an animal’s environment. The nanotechnology approach in developing biosensing tools offers direct benefits through simpler testing, smaller size, greater accuracy, faster results and faster responses to key health threats in the farm animal sector [12].

3.3. Animal health databases and alert notification
Sharing information via new ICTs provides real-time notifications on disease events, enabling successful control of epidemics. For example, Members of the OIE must report within 24 h the occurrence of animal diseases listed by the OIE, the emergence of new diseases and significant epidemiologic events. For this purpose in 2006, the OIE created the World Animal Health Information System (WAHIS) that is coupled with the WAHIS interface and provides information on 117 diseases [13]. The WAHIS interface provides public access to all data as soon as they are validated by the OIE. In addition, the OIE developed their WAHIS-Wild interface that provides information about non OIE-listed diseases in wildlife. Implementation of WAHIS has significantly improved and accelerated the OIE’s capacity to relay information about the global animal disease situation, and the member states’ awareness of the disease situations in other countries [14]. Due to rapid technological progress, the OIE is working on redesigning and upgrading WAHIS, and a new platform is expected to be completed by the end of 2019. It should make it easier for users to collect and report information and upload data from their own databases, and it will include new features like geospatial data, interconnection with other international or regional information systems, and the WAHIS Alert mobile application.

The EU has developed a similar notification system, the animal disease notification system (ADNS). ADNS is a web-based tool that ensures immediate notification of alerts and detailed information about outbreaks of animal diseases in the member countries, but use by other non-EU countries is enabled on a voluntary basis. Since 2012, a joint project between the EC and the OIE has worked on linking WAHIS and ADNS.
Some other global electronic databases and alert notification systems are RASFF – rapid alert system for food and feed (EFSA – European Food Safety Authority), EMPRES-i – global animal disease information system (FAO – Food and Agriculture Organisation of the United Nations) and PubMed (ISID – International Society for Infectious Diseases), while one database even covers health events of joint interest for humans, animals, plants and the environment (One Health). There are also country-level electronic animal health and production databases for official or public use [15-18].

3.4. The animal and animal products trade and veterinary certification

The EU system of traceability within the food supply chain includes animal identification, certification of shipments and products, and the ICT tool, trade control and expert system (TRACES). TRACES is a web-based multilingual online management tool for all sanitary requirements on intra-EU trade and importation of animals, semen, embryos, food, feed and plants. It was developed after outbreaks of classical swine fever in the EU in 1997 and launched as a compulsory tool for all EU member states on 1 January, 2005 [18]. The main objective of TRACES is to digitise and harmonise certification processes and linked procedures, allowing traceability through monitoring the movements of consignments within the EU and from non-EU countries, facilitating information exchange and improving risk management. This should ensure prompt reactions to health threats. [19]

Electronic animal identification (EID – injectable, ear-tag and bolus transponders) that began emerging in the 1980s is increasingly widespread and is becoming even more inevitable with digitisation of databases [20]. Digital storing and monitoring of data is a norm for in-house quality control systems in food production establishments.

3.5. Animal disease data analysis

The SPS agreement provisions rendered the mandatory use of epidemiological principles in prioritisation, risk assessment and surveillance of animal disease. Since population-based and observational surveys as methodologies used in epidemiological research are founded on biostatistics (i.e. representativeness and quantifiable estimation of parameters, trends, differences and errors), this made them complementary with ICT, and many tools are available to translate formulas, mathematical laws and prediction models into needed solutions. Among the first computer software packages were Epi Info™ and EPISCOPE, which covered many epidemiological principles and calculations, and are intended to be used both in teaching of epidemiology and analysis of field data [21, 22]. These products include sample size calculations, statistical comparison and data analysis for different study designs and diagnostic testing protocols. Products are available for data geo-referencing, spatial analysis and epi modelling (i.e. QGIS, R, INTERSPREAD PLUS, OH-SMART), risk analysis (@Risk), web-based epi calculators (i.e. EpiTools) and designing risk-based disease surveillance (i.e. RISKSUR).

Geographic information systems (GIS) are long recognised as an important asset in the field of surveillance and monitoring of animal diseases [23]. GIS functions with geographical data, farm locations and disease information are used in recording and reporting information, epidemic emergencies, cluster analysis, modelling disease spread and planning control strategies. These systems are now coupled with unmanned aerial vehicles (drones) mainly used to acquire real-time data and to constantly update the risk-related information in hotspot areas. The detailed ecological and environmental data they collect can be used for assessing factors (e.g. movement and distribution of people, animals, and pathogen-carrying insects) influencing the transmission of infectious diseases [24].

3.6. Tools for veterinary education

The introduction of problem-based learning into veterinary curriculums expanded the use of ICTs in veterinary education, since these tools offer adaptable, affordable and interactive settings for veterinary students to gain required knowledge [25]. Traditional classroom lectures today almost always include projected presentations that have moved away from one-dimensional presentations.
towards immersive, tech-enabled and interactive learning. In addition to Microsoft PowerPoint (for Windows) and Keynote (for iOS), there are numerous other software products for presentations available (i.e. Google slides, Prezi), classroom management software products (i.e. ClassFlow, Insight), and add-on tools for interactive lectures (i.e. Mentimeter, Pool Everywhere).

Spatial computing, which incorporates virtual reality (VR) and augmented reality, has been used in human medical care and education and recently expanded to veterinary education. Examples are the VR project called EZ Anatomy, a realistic anatomy training tool for veterinarians, and also haptic cow and haptic horse (veterinary virtual reality simulators) [26].

Web representation of veterinary faculties worldwide has been expanded to platforms that serve not only for sharing information and administration of programs and courses (i.e. enrolment, exam scheduling, student records), but are increasingly teaching podiums with e-learning and long-distance learning as integral segments of regular coursework.

3.7. Animal health diagnostics

According to the announcement from 2018, a team of scientists led by Brunel University London is working to develop a molecular test and a smartphone app that, when used together, will detect six key pathogens in poultry [27]. The idea behind the project is that farmers collect samples from birds using a matchbox-sized instrument that screens the DNA and RNA. The device connects wirelessly to the app to display the results, which can also feed into a central database and help track outbreaks. The whole process takes less than an hour. Similar examples are already developed for real-time field diagnostics of foot-and-mouth disease [28].

ICT data management systems are now commonly used in laboratories. The laboratory information management system (LIMS) is recognised as a powerful tool in many aspects of laboratory work including harmonisation and completeness of input and output data, laboratory accreditation (ISO IEC 17025), public health surveillance, outbreak investigations, and pandemic preparedness. This system enables active formal checks and controls on business rules and inter/intra automatic data exchange between laboratories [29].

4. ICT/AI technologies and trends – demands or opportunities for veterinarians

Most of the ICT tools used today in veterinary medicine are still strictly related to data collection, analysis, management and dissemination, since the tools have inherit capacity to organise and deal with large volumes of data. As never before, information on new disease outbreaks and/or biological emergencies are shared to national and international authorities, farmers and consumers very rapidly after the disease occurrence. Social networks and other informal, non-governmentally controlled, communication channels globally disseminate information on serious food-borne incidents in tourist resorts even before patients are hospitalised. Using the same resources, our veterinary clients are better informed than ever on health issues of their pets or productivity failures of their farm animals, and are requesting the best quality veterinary services at the cheapest price. The ICT world is putting the veterinary profession under constant and increasing pressure.

Development of AI tools and their application in veterinary medicine, in contrast with some other services and professions, are in the very early phase. A significant amount of animal health, welfare, production and food safety data are already available at aggregated levels (not only country, but regional or even global). Now, though, we are faced with the question of how to merge the data with ICT/AI knowledge and tools for the benefit of our profession and so we can more efficiently respond to requests from clients, industry and society. Though a common concern and perception of all professions prevails that the increasing influence and development of ICT/AI will result in loss of jobs and negatively impact the welfare of personnel, scientists are in agreement that it will be much more difficult to replace humans with machines and software in less routine jobs that demand the simultaneous use of a wide range of skills, and that involve dealing with unforeseen scenarios [30]. How routine is our profession, and what kind of professional development is foreseen in the future? This paper is not intended to answer those and other related, important questions. However, in any
attempt to do that, we need to acknowledge fact that two particularly important non-human abilities that ICT/AI possesses are connectivity and updateability [30], and both of them are highly appreciated and demanded by our veterinary clients today. It seems we veterinarians still rely on the axiom that technology is never deterministic, and the fact that something can be done does not mean it must be done. For sure, it is difficult to predict what sort of impact machine learning and automation will have on different professions in future. However, we must be aware that if the focus of our profession, as it is today, stays on processing information, i.e., collecting suitable data, analysing that data and producing a diagnosis, it might be easily replaced by technology and animal owners. For example, companion animal owners will probably have an AI VET app on their smartphone decades before a reliable technician might be virtualised. As improvements to ICT and AI continue, to interact with these tools, our veterinary profession will need to repeatedly learn new skills and introduce changes.

The reality of change in today’s world is axiomatic, but compared to the expanding use of ICT in our field, there is a lack of scientific research that address it, even for systems already in use (i.e. TRACES, EMPRES, ADNS). Our pilot study (not published) identifying farm animal client interest and expectation in ICT-based veterinary consultation platforms found the majority of our clients are active users of ICT resources when seeking information on animal diseases, treatments and market opportunities. However, in the same study, veterinarians showed significant reluctance to use ICT to provide their services to their obviously adaptable clients. Are we to remain only sporadic operators of new technologies and regress into a new era of veterinary science, from being a well-established and necessary profession back to being a vocation doomed to extinction?

Current work on merging biological data, collected via biosensors, drones, or other tools with ICT and/or AI platforms and algorithms is expected to accelerate the changes and challenges ahead of us. The specific symbiosis of bio- and information technologies has opened a new era in health and food production. To be controversial, we see this as a chance for all veterinary professionals to evolve from being passive followers of such development to being leaders and collaborators. Significant changes in our education and more interdisciplinary research will be needed to support this projection.

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