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REVIEW ARTICLE

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How does innovative technology impact nursing in infectious diseases and infection control? A scoping review

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Abstract

Aim: Considering the increasing number of emerging infectious diseases, innovative approaches are strongly in demand. Additionally, research in this field has expanded exponentially. Thus, faced with this diverse information, we aim to clarify key concepts and knowledge gaps of technology in nursing and the field of infectious diseases.

Design: This scoping review followed the methodology of scoping review guidance from Arksey and O'Malley.

Methods: Six databases were searched systematically (PubMed, Web of Science, IEEE Explore, EBSCOhost, Cochrane Library and Summon). After the removal of duplicates, 532 citations were retrieved and 77 were included in the analysis.

Results: We identified five major trends in technology for nursing and infectious diseases: artificial intelligence, the Internet of things, information and communications technology, simulation technology and e-learning. Our findings indicate that the most promising trend is the IoT because of the many positive effects validated in most of the reviewed studies.

KEYWORDS

infection control, infectious disease, nursing, nursing performance, quality of care, technology

1 | BACKGROUND

At present, technology is almost inseparable from our daily lives. Currently, according to the online statistics portal, Statista, 5.28 billion people (67.95%) own a mobile device globally (Turner, 2018). Most paperwork is in the electronic form, particularly in the nursing and medical fields. Without this electronic paperwork, work seems complicated. A quick search in electronic database search engines reveals that the number of studies on technology in the medical field has increased exponentially. The demand for research in technology over the past decades has become more necessary, making the world more connected (Korhonen et al., 2015).

Technology in health care has been used to assist daily clinical practice and clinical processes, such as electronic health records and health information technology. Recording mass data allows hospitals to develop efficient clinical workflows and facilitate decision-making processes to improve patient safety (DeMellow & Kim, 2018; eHealth, 2012; Yanamadala et al., 2016).

In the field of infectious diseases, due to the increasing number of emerging diseases, innovative approaches are essential. In particular, during the pandemic of coronavirus disease (COVID-19), some innovative technologies have gained attention. Using automatic monitoring and detection in disease outbreaks, such as mobile devices, cloud computing, the Internet of things (IoT) and geographic

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information systems, has the potential to improve the quality and safety of health care. These innovative approaches can eliminate the need for human intervention and have sparked more research for real-world evidence (Goldschmidt, 2020; Lounis et al., 2016; McCarthy et al., 2019; Sareen et al., 2017).

This scoping review aims to clarify key concepts and characteristics of innovative technology in nursing and the infectious disease field, to identify knowledge gaps and investigate how research is conducted and to map the field of innovative technology in each nursing activity and infectious diseases (Arksey & O'Malley, 2005; Levac et al., 2010). The research questions were focussed on the following: (a) What are the technology trends in the infectious disease nursing area? (b) How does innovative technology impact nursing and infectious diseases?

2 | METHODS

The protocol of our review is not registered. This review followed the methodology of scoping review guidance from Arksey and O'Malley and the PRISMA extension for scoping reviews (PRISMA-ScR) checklist (Arksey & O'Malley, 2005; Tricco et al., 2018). In terms of improving the methodological approach and optimize the rigour of our finding, an additional processual suggestion from Levac et al. (2010) was taken into account. To select, retrieve and chart the data, the processual recommendation was used to define relevant studies by adjusting validity with resource feasibility and the iterative process (Levac et al., 2010; Peters et al., 2015). For methodological quality (risk of bias) assessment, no formal methodological quality assessment of the included articles was conducted under guidelines for conducting a scoping review (Arksey & O'Malley, 2005; Munn et al., 2018; Peters et al., 2015).

2.1 | Eligibility criteria

We searched all the scientific papers published, focussing on the latest technology and innovative developments in nursing and infection control. To minimize missing any meaningful and potentially relevant articles, all types of study designs and target settings were included. All electronic databases were screened in March 2020.

The time frame for publication was limited to the last 6 years, which we considered a reasonable period to define the up-to-date technology. Articles are limited in English, peer-reviewed journals and availability of full-text contents. Articles were excluded if the studies were reviews, case reports, studies without an impact on healthcare workers' activities, and terms such as surgical robot and telehealth were also excluded.

2.2 | Information sources

A comprehensive literature search was conducted the following electronic databases from March 2014–March 2020: PubMed, Web of Science, IEEE Explore, EBSCOhost, Cochrane Library and Summon (Aix-Marseille university network). In addition, a step-by-step review method of preselected literature and hand-searching in key journals (*Journal of Infection and Public Health*, *Infection Control & Hospital Epidemiology*, *Journal of Clinical Infectious Diseases*) was performed as manual search processes to avoid losing any potentially relevant articles in databases. To address our central research question and adopt a broad approach, the key search terms were based on technology, nursing and infectious diseases.

2.3 | Search strategy

The following search terms were used: (Technology OR Technologies OR Information systems OR Data system) AND (Nursing OR nurse OR Care OR Caring) AND (infectious disease OR Infection OR Control, Infection OR Universal precautions OR Infection, Nosocomial OR Associated Infection, Healthcare OR Cross Infection OR Hand hygiene).

2.4 | Data charting process and data items

All the search results were imported into Zotero 5.0 for Windows, and all the data (e.g. title, authors, date, and abstracts) were exported into an Excel file for screening. After removing duplicate articles, two authors independently screened potentially relevant articles by examining the titles, abstracts and the full text. A data charting form was determined and completed after the discussion of results.

We extracted article characteristics, including the author names, date of publication, study design, country, target setting, nursing activity, technology used, infectious disease, sample size, study period and outcome. These characteristics were collected in an Excel file.

2.5 | Synthesis of results

For each study, we identified the related nursing category, infectious disease area and type of technology used, if one study used several technologies, we identified the more dominant one. To focus on the technology trends in nursing and infectious diseases, we counted the numbers of studies by technology category for each nursing category and infectious disease. To determine the impact of technology on nursing in infectious disease, we analysed each article and defined four categories of outcome: efficiency, effectiveness, performance and quality (Welton, 2013). Therefore, we counted the numbers of studies by each technology category and each outcome category.

3 | RESULTS

3.1 | Overview of the search results

In total, 708 citations were identified from searching in electronic databases, including 629 through database searching and 79 through hand-searching. After the removal of duplicates, 532 articles were retrieved for the title and abstract screening, and 389 articles were excluded, with 143 full-text articles to be assessed for eligibility. Of these, 66 articles were excluded due to the following: 53 were off topic, 8 were review articles, 3 had irretrievable full-text content, and 2 were commentary articles. Finally, 77 articles remained eligible for this review and included 23 different countries (Figure 1).

Table 1 summarizes the characteristics of the included articles. Among the 77 articles included in the analysis, 30 were quasi-experimental studies, 14 were validation studies, 13 were analytic observational studies, 13 were descriptive observational studies, and 7 were randomized controlled trials.

This review grouped all the technologies found into seven categories: (1) IoT and wireless (*N* = 23): The IoT represents a connected object that transfers data to the Internet automatically without any human interaction, such as an automatic electronically assisted surveillance system ("Institute of Electrical and Electronics Engineers (IEEE)," n.d.); (2) artificial intelligence (AI) (*N* = 20): AI includes machine learning and deep learning and provides the analysis of massive information (big data) in prediction, autoclassification, autofeedback, early detection and decision support; (3) information and communications technology (ICT) (*N* = 14): ICT represents technologies providing access and communication through digital network, namely electronic health records, hospital information systems, video records, texts and messaging-support systems; (4) E-learning (*N* = 6):

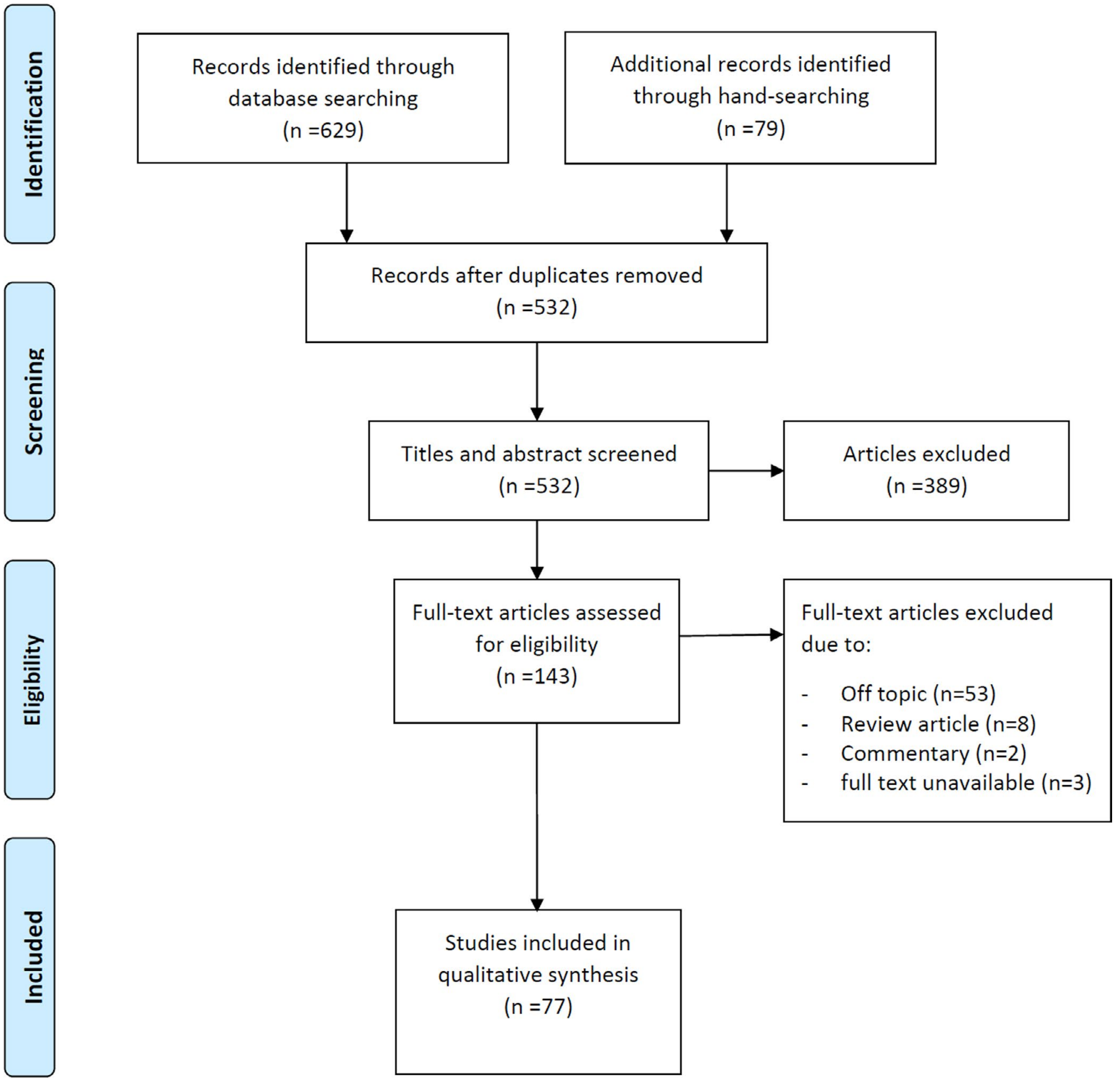

FIGURE 1 PRISMA flow chart for scoping review

TABLE 1 Characteristics of included articles

Characteristics	Categories	N	(%)
Study Design	Quasi-experimental	30	38.96
	Validation study	14	18.18
	Analytic observational	13	16.88
	Descriptive observational	13	16.88
	Randomized control trial	7	9.09
Technology	IoT & wireless	23	29.87
	AI	20	25.97
	ICT	14	18.18
	E-learning	6	7.79
	Simulation technology	6	7.79
	Mobile application	4	5.19
	Sensors	4	5.19
Nursing	Infection Prevention and Control	46	59.74
	Nursing management	13	16.88
	Nursing education	12	15.58
	Nursing assessment	6	7.79
Infection diseases	Healthcare-associated infections	50	64.94
	Emerging Infectious	8	10.39
	Sepsis	7	9.09
	Antimicrobial Stewardship	5	6.49
	Urinary tract infections	3	3.90
	Respiratory tract infections	2	2.60
	Blood culture contaminants	1	1.30
	Pelvic inflammatory disease	1	1.30

TABLE 2 All nursing activities included in nursing category

Nursing Category	Activity	N
Infection Prevention and Control	Hand hygiene	22
	Predicting and detection	18
	Quality improvement	6
Nursing management	Decision support/making	7
	Patient management	4
	Care management	1
Nursing education	Continue training	10
	School training	2
Nursing assessment	Assessment	4
	Recording	2

also called distance education, it works with the Internet or digital device without face-to-face contact. It has been used increasingly in nursing and healthcare knowledge management; (5) simulation technology (*N* = 6): it is an approximate imitation and has been widely used in skills training or nursing education to improve competence, such as using a high-fidelity simulator (human or robot); (6) mobile application (*N* = 4): a software program running on a smartphone or tablet; (7) sensors (*N* = 4): the measure of physical movements or chemical changes that can be used to control other devices, such as an alarm system, automated record or reminder.

This review analysed all the activities related to nursing, grouped into four major categories: (1) infection prevention and control as an essential element of patient safety and the quality of care; for this reason, the consequence impacts not only patients but also healthcare workers. Forty-six articles were identified in this category, including hand hygiene (*N* = 22), prediction and early detection of disease (*N* = 18) and quality improvement (*N* = 6); (2) nursing management: 13 articles were identified in this category; it is an important part of nursing to improve nursing quality and patient satisfaction. It includes all processes, including planning or organizing, such as decision support/making (*N* = 7), patient management (*N* = 4) and care management (*N* = 1); (3) nursing education: 12 articles were identified, including healthcare workers continuous training (*N* = 10) and school training for students (*N* = 2); (4) nursing assessment: 6 articles were in this section; it is the first step and fundamental in the nursing process and daily care, such as the measurement of patient's clinical signs and symptoms. Urinary tract infection assessment (*N* = 2), image assessment (*N* = 1), vascular assessment (*N* = 1), surgical drain output measurement (*N* = 1) and temperature measurement (*N* = 1). Table 2 summarizes the activities in each nursing category.

In the section of infectious diseases, this review grouped several types of infection, such as healthcare-associated infections (HAIs) and emerging and other infectious diseases. Fifty articles were identified in HAIs, such as contact-related HAIs (*N* = 23), non-specific HAIs (*N* = 12), central line-associated bloodstream infection (CLABSI) (*N* = 7), ventilator-associated events (VAEs) (*N* = 3), catheter-associated urinary tract infection (CAUTI) (*N* = 2), surgical site infections (SSIs) and *Clostridium difficile* infection (*N* = 1). Likewise, 5 articles were identified in emerging infectious diseases, including COVID-19 (*N* = 2), Ebola virus (*N* = 2), Zika virus (*N* = 2), HIV (*N* = 1) and infectious diarrhoea (*N* = 1). Others infectious diseases included sepsis (*N* = 7), antimicrobial resistance (*N* = 5), urinary tract infection (*N* = 3), respiratory tract infections (*N* = 2), pelvic inflammatory disease (*N* = 1) and blood culture contaminants issue (*N* = 1) (Table 3).

3.2 | Synthesis of results

Tables 4,5 show the technology trends in nursing and infectious diseases. To highlight technology trends in nursing, this review counted the numbers of studies by each technology category for each nursing category. Most of the studies were focussed on IPC (59.74%). Twenty studies addressed the utilization of the IoT and wireless, 16 studies were focussed on AI, and 8 studies were focussed on using ICT. Moreover, 16.88% and 15.58% of the studies were focussed on nursing management and nursing education. Regarding nursing management, 6 studies addressed using ICT and 3 studies addressed

TABLE 3 All infectious diseases and issue included in infection category

Infection Category	Infection disease	N
Healthcare-associated infections	Contact-related HAIs	23
	non-specific	12
	Central line-associated bloodstream infection (CLABSI)	7
	Ventilator-associated events (VAE)	3
	Catheter-associated infection urinary tract infection (CAUTI)	2
	Surgical site infections (SSIs)	2
	C. Difficile infection	1
Emerging Infectious	COVID-19	2
	Ebola	2
	Zika	2
	HIV	1
	Infectious diarrhoea	1
Others	Sepsis	7
	Antimicrobial resistance	5
	Urinary tract infections	3
	Respiratory tract infections	2
	Blood culture contaminants	1
	Pelvic inflammatory disease	1

using AI. Regarding nursing education, e-learning (*N* = 6) and simulation technology (*N* = 5) were the most used technologies in this area. Only 7.79% of studies focussed on nursing assessment, including using IoT (*N* = 2), sensors (*N* = 2), AI (*N* = 1) and mobile applications (*N* = 1).

To highlight the technology trends in infectious diseases, this review counted the number of studies by each technology category for each infectious disease. Most studies were focussed on HAIs (64.94%). Among them, 19 studies used IoT and wireless technology, 10 studies used AI and machine learning and 8 studies used ICT. In emerging diseases, four technologies were used frequently, AI (*N* = 3), IoT and wireless (*N* = 2), simulation technology (*N* = 2) and ICT (*N* = 1). In sepsis, 5 studies used AI technology and another two studies used ICT and simulation technology. For assisted antimicrobial stewardship, e-learning (*N* = 2), ICT (*N* = 2) and AI were used. The types of technology involved in nursing infectious diseases are represented in Figure 2.

To analyse the impact of technology on nursing and infectious diseases, this review classified each included article by their study results. Seventy-one among 77 articles were analysed for the outcome category, and this review defined four aspects of outcome.

We considered efficiency as minimizing unnecessary time and efforts of nursing (doing the right thing), effectiveness as optimizing the clinical practice of nursing (doing things right), performance as optimizing the process of nursing, and quality as minimizing the healthcare system errors from daily care to provide patient safety (Welton, 2013). Table 6 shows the number of studies by each technology category and each outcome category: 35.2% of studies (*N* = 25) analysed effectiveness, 26.8% of studies (*N* = 19) analysed performance, 22.5% of studies (*N* = 16) analysed quality, and 15.5% of studies (*N* = 11) analysed efficiency. According to our analysis, the technology attempt improved nursing as follows: 12 studies using the IoT showed the effectiveness, and 13 studies using AI showed the performance. To visualize the technology trends of nursing outcomes in infectious diseases, Figure 3 illustrates the impact of technologies on outcomes in nursing. Table 7 enumerates the details of the technology used in each nursing category and each infectious disease, as well as the target setting and outcome aspects.

4 | DISCUSSION

In the 77 papers reviewed, five major trends in technology were identified for nursing and infectious diseases: (1) AI, (2) IoT and wireless, (3) ICT, (4) simulation and (5) e-learning. Of these five trends, those that had the greatest impact have been AI and IoT, whereas e-learning has not been sufficiently studied to establish how much of an impact they have had so far.

Our findings indicate the most promising trend is the IoT because many positive effects have been validated by multiple research studies in those areas. We summarized the most used technology in each nursing field below.

4.1 | Infection prevention and control

4.1.1 | Hand hygiene

Contact-related HAIs are avoidable issues with good hand hygiene. The IoT was the most used technology for hand hygiene and seems to be an effective way to enhance healthcare workers (HCWs) self-awareness. Seventeen studies used the IoT for hand hygiene monitoring, such as the automatic and electronically assisted hand hygiene surveillance system (AHHMS) in hospitals, intensive care units, infectious disease wards and inpatient departments. Among the 17 studies, most used a cloud-based server and a wearable device (electronic badge, tag or bracelet) with or without automatic feedback (reminder) to improve the hand hygiene compliance rate. Four of them did not demonstrate any improvement due to technical problems, a low HCWs acceptance or low participation in long-term observation. However, two of these studies still reported a significant improvement in hand hygiene compliance (Benudis et al., 2019; Marques et al., 2017; Scheithauer et al., 2018; Stella et al., 2019). Eight studies concluded that AHHMS could improve hand hygiene activity, and some of them showed that AHHMS measured lower hand hygiene compliance (26%–39%) compared with human observation (65%–95%) (Boyce, Cooper, et al., 2019). By contrast, two studies that combined a reminder (chemical sensors) reported that hand hygiene compliance was not sustained after AHHMS removal,

TABLE 4 Number of studies by technology category and nursing activities

Technology	Nursing activity				
	Infection prevention and control	Nursing assessment	Nursing education	Nursing management	Grand Total
AI	16	1	0	3	20
E-learning	0	0	6	0	6
ICT	8	0	0	6	14
IoT & wireless	20	2	0	1	23
Mobile application	1	1	1	1	4
Sensor	1	2	0	1	4
Simulation technology	0	0	5	1	6
Grand Total	46	6	12	13	77

TABLE 5 Number of studies by technology category and infectious diseases

Technology	Infection diseases category								
	Healthcare-Associated infections	Emerging infections	Sepsis	Antimicrobial stewardship	UTI	RTI	PID	Blood culture contaminants	Grand Total
AI	10	3	5	1	0	1	0	0	20
E-learning	4	0	0	2	0	0	0	0	6
ICT	8	1	1	2	0	0	1	1	14
IoT & wireless	19	2	0	0	2	0	0	0	23
Mobile application	2	0	0	0	1	1	0	0	4
Sensor	4	0	0	0	0	0	0	0	4
Simulation technology	3	2	1	0	0	0	0	0	6
Grand Total	50	8	7	5	3	2	1	1	77

with the rate dropping from 62.61%–24.94%, and one study demonstrated an 8-week sustainability. The sustainability of AHHMS during the long term remains uncertain (Dyson & Madeo, 2017; Pong et al., 2018). However, AHHMS could reduce HAIs. Three studies that combined AHHMS with a visual cue showed a negative correlation between the hand hygiene compliance and rate of CLABSI and CAUTI: one study showed that the improvement in compliance was related to a significant reduction in the rate of methicillin-resistant *Staphylococcus aureus* infection, but one study demonstrated a non-significant reduction in the HAIs rate (Boyce, Laughman, et al., 2019; McCalla et al., 2018).

Another four studies were focussed on the utilization of the Wi-Fi dispenser and counting systems in hand hygiene improvement. Three of them had positive results, and one reported a negative performance. In this case, an anonymous approach seems more acceptable for HCWs, but compliance was difficult to assess.

Regarding hand hygiene, the AI-based hand hygiene training system was used for automatic feedback in training and clinical practice. Three studies considered the AI training system was a cost-effective method in monitoring and improving the quality and quantity of hand hygiene, but one study showed that it did not affect the compliance rates. According to those results, AI-based training might improve the quality of hand hygiene but the effect on compliance remains unclear (Geilleit et al., 2018, p. 1; Kwok et al., 2015, p. 1; Lacey et al., 2019). Furthermore, one study validated a hand hygiene program that combined sensors with a video in AI gesture recognition, suggesting that this method is suitable for further research (Kutafina et al., 2016).

4.1.2 | Predicting and early detection of infection

In this field, AI is the most used technology. Using big data from the hospital information system and electronic clinical records afford developing models to predict and detect emerging diseases, HAIs and sepsis. Two studies used the data of the national surveillance system to predict the epidemic of infectious diarrhoea and predicted the geographic expansion of zika virus infection. Seven studies used electronic medical records data to classify new risk factors to predict HAIs earlier than those using classical risk factors. Those new characteristics and factors could help improve HAIs control strategies and early identification; they considered this innovation is a

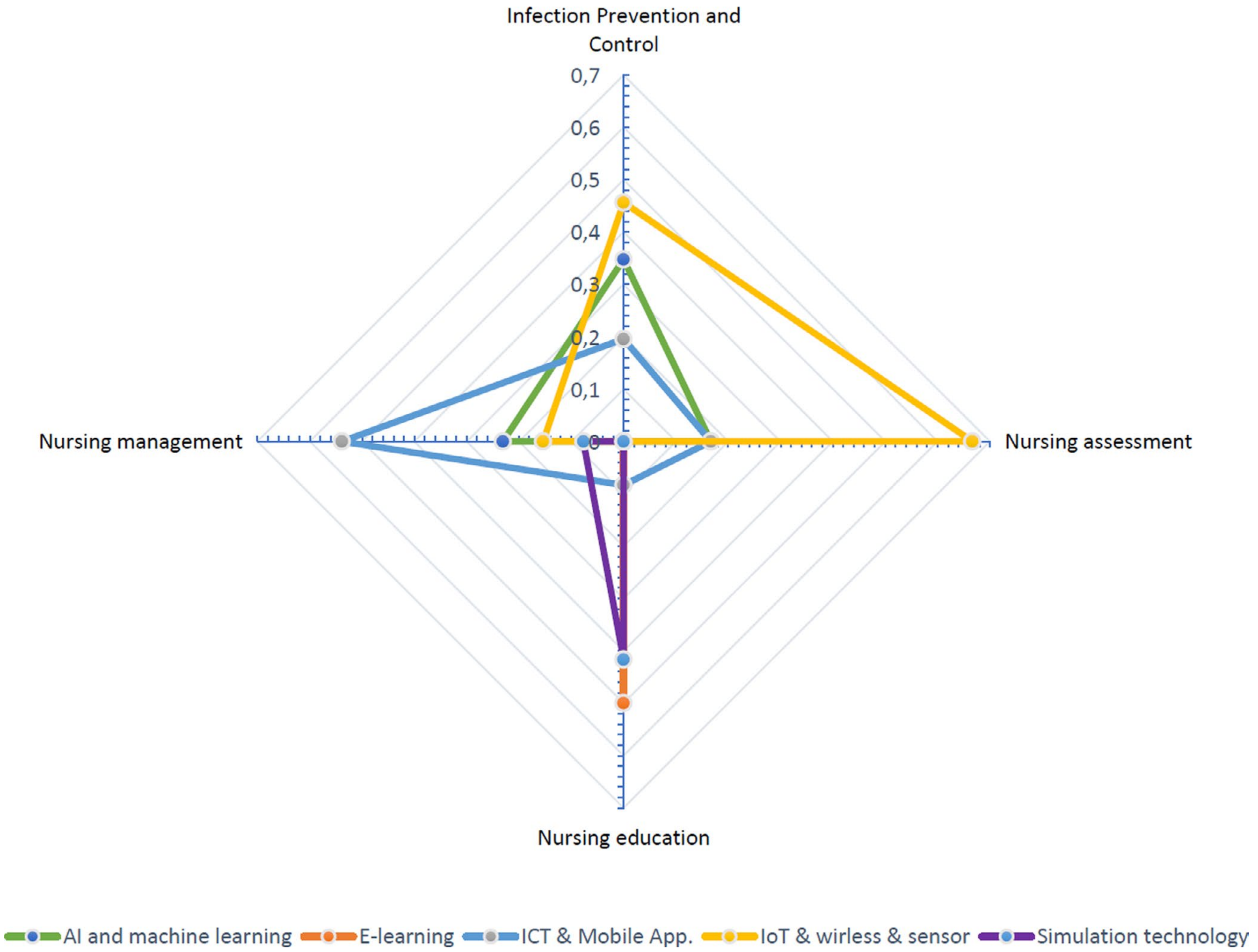

FIGURE 2 The types of technology involved in nursing infectious diseases. This chart presents the percentage of technology in each nursing category

TABLE 6 Impact of technology on nursing and infection diseases. Numbers of studies by each technology category and each outcome category

	Impact category				
Technology	Effectiveness	Efficiency	Performance	Quality	Total
AI	2	4	13	1	20
E-learning	1	1	0	3	5
ICT	3	4	4	3	14
IoT & wireless	12	1	2	4	19
Mobile application	2	1	0	1	4
Sensor	3	0	0	1	4
Simulation technology	2	0	0	3	5
Total	25	11	19	16	71

cost-effective approach to reduce the infection rate and generate new strategies of disease control (de Bruin et al., 2016; Li et al., 2019; Nekkab et al., 2017; Parreco et al., 2018). To use the patients' data more efficiently and detect HAIs sooner, one study integrated multimedia with a simulator system to process patient records automatically to diagnose and predict CLABSI. This automatic surveillance system helps to reduce the CLABSI rate, and 87% optimization was achieved (compared with traditional prevention) (Noaman

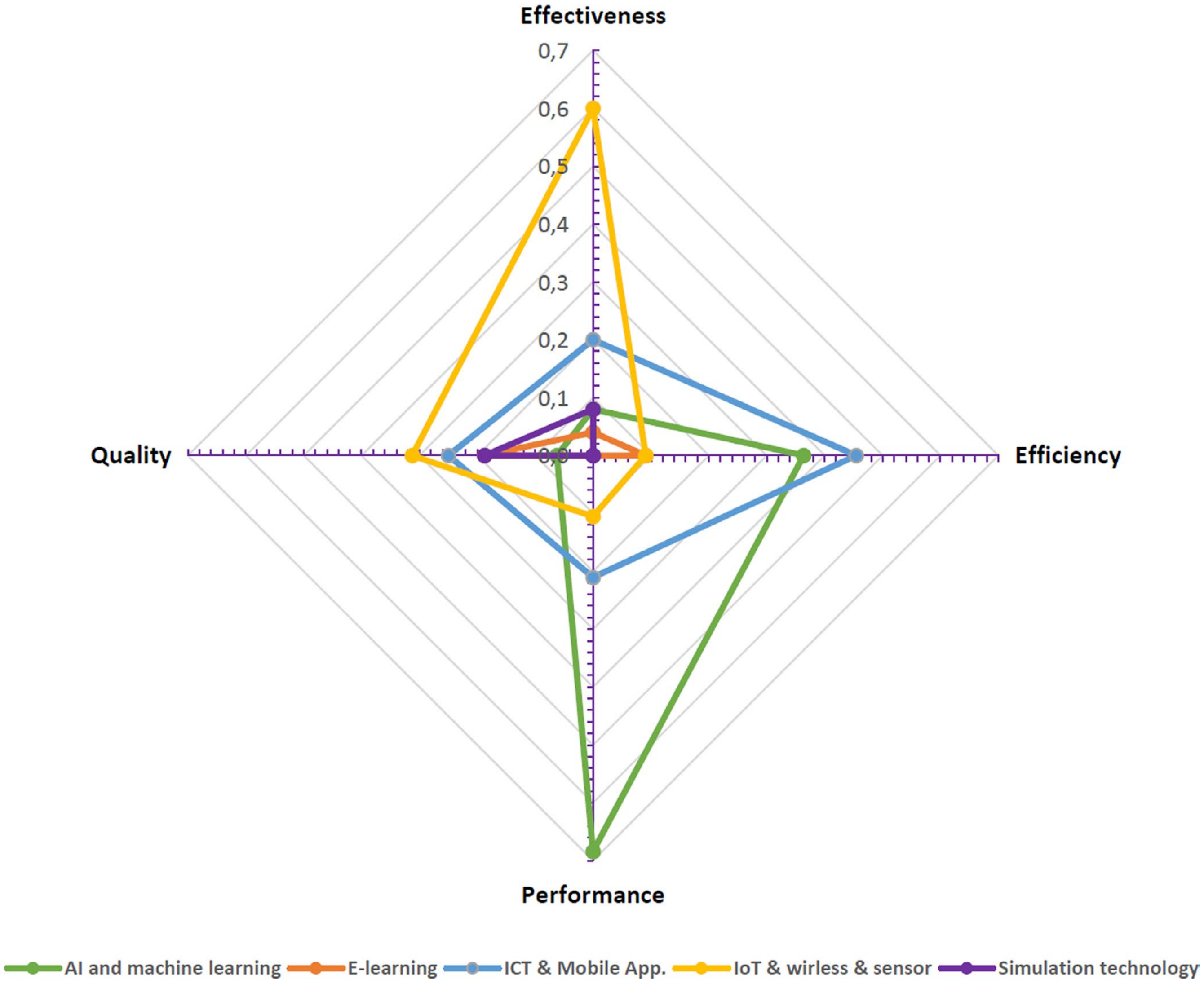

FIGURE 3 The technology trends of nursing outcomes in infectious diseases. This chart presents the percentage of technology in each outcome category

et al., 2020). Four studies showed that using machine learning and deep learning in imaging data and vital signs data was accurate to diagnose tuberculosis and detect sepsis earlier, reducing antibiotic use and antibiotic duration and improving patient outcome. Additionally, to improve sepsis recognition and detect sepsis patients sooner after hospitalization, one study used geographic information and clinical information systems to help the early diagnosis of sepsis in patients in the community. However, as common limitations of AI, unknown human factors or non-linear relationships might influence the prediction and its accuracy. Thus, AI can offer an additional opinion in prediction and early detection but whether it reflects the real world remains uncertain.

To face emerging diseases and improve patient safety, the IoT was also used in this area. One study combined the IoT with in-home sensory devices for urinary tract infection detection in-home care, an approach that affords real-time monitoring and could provide more effective and preventative care to reduce avoidable urinary tract infection events for home care patients. To face emerging diseases, the IoT can also be combined with GPS to classify a patient's status and identify the spread of Zika virus and the risk area. However, this method requires a smartphone for each patient and some ethics issues exist regarding personal data (Akhtar et al., 2019; Husnayain et al., 2020; Sareen et al., 2017).

4.1.3 | Quality improvement

Five studies used electronic medical records and the hospital information system in quality improvement programs to reduce HAIs (CAUTI, CLABSI and SSIs) and improve antibiotic stewardship efforts. They reported that using ICT was a cost-effective approach for quality improvement work. A relationship was found between psychosocial factors and HAIs. According to the cross-data from a self-reported questionnaire and hospital information system,

TABLE 7 This table indicate the detail of technology used in each nursing category, each infectious disease and target setting

Nursing category	Nursing activity	Infection category	Infection disease	Technology category	Setting cat	Outcome
Infection prevention and control	Hand hygiene	Healthcare-associated infections	Contact-related	AI	Hospital	Efficiency
				AI	OPD	Efficiency
				AI	Surgical unit	Quality
				IoT & wireless	Hospital	Effectiveness
				IoT & wireless	Hospital	Effectiveness
				IoT & wireless	Hospital	Effectiveness
				IoT & wireless	Hospital	Effectiveness
				IoT & wireless	Hospital	N/A because of low participation
				IoT & wireless	ICU	Effectiveness
				IoT & wireless	ICU	Quality
				IoT & wireless	ICU	N/A because of technical issues
				IoT & wireless	ICU	N/A because of technical issues
				IoT & wireless	Infectious Diseases Ward	Quality
				IoT & wireless	Inpatient units	Quality
				IoT & wireless	Inpatient units	N/A because of nuge did not affect HH
				IoT & wireless	Multi-centre	Effectiveness
				IoT & wireless	OPD	Effectiveness
				IoT & wireless	Rehabilitation unit	Effectiveness
				IoT & wireless	Rehabilitation unit	Effectiveness
				IoT & wireless	Rehabilitation unit	Effectiveness
				Mobile App.	Hospital	Quality
				Sensor	N/A	Effectiveness

(continued)

TABLE 7 (continued)

Nursing category	Nursing activity	Infection category	Infection disease	Technology category	Setting cat	Outcome
	Predicting and detection	Emerging Infectious	COVID-19	ICT	N/A	Performance
			Infectious diarrhoea	AI	National surveillance system	Performance
			Zika	AI	National surveillance system	Performance
			Zika	IoT & wireless	Community	Performance
		Healthcare-associated infections	non-specific	AI	Hospital	Performance
			non-specific	AI	ICU	Performance
			non-specific	AI	Multi-centre	Performance
			non-specific	AI	ICU	Performance
			CLABSI	AI	ICU	Performance
			CLABSI	ICT	Hospital	Performance
			C. Difficile infection	AI	Hospital	Performance
			VAEs	AI	ICU	Efficiency
		Other	Tuberculosis	AI	Hospital	Performance
			Sepsis	AI	ICU	Performance
			Sepsis	AI	ICU	Performance
			Sepsis	AI	Multi-centre	Performance
			Sepsis	ICT	Emergency Department	Performance
			Urinary tract infection	IoT & wireless	Home care	Effectiveness
	Quality improvement	Healthcare-associated infections	All reasons-general	ICT	ICU	Quality
			CLABSI	ICT	ICU	Effectiveness
			CAUTI	ICT	Hospital	Effectiveness
			CAUTI	ICT	Hospital	Quality
			SSIs	IoT & wireless	Operation suite	Quality
		Other	Antimicrobial resistance	ICT	Hospital	Efficiency
			Sepsis	AI	ICU	Performance

(continued)

TABLE 7 (continued)

Nursing category	Nursing activity	Infection category	Infection disease	Technology category	Setting cat	Outcome
Nursing management	Decision support/ making	Healthcare-associated infections	non-specific	ICT	Hospital	Efficiency
			non-specific	ICT	ICU	Efficiency
		Other	Antimicrobial resistance	AI	ICU	Effectiveness
			Antimicrobial resistance	ICT	Emergency Department	Efficiency
			Contaminated blood culture	ICT	Emergency Department	Quality
			Sepsis	AI	ICU	Effectiveness
			Sepsis	AI	ICU	Performance
	Care management	Healthcare-associated infections	VAEs	Sensor	N/A	Effectiveness
	Patient management	Emerging Infectious	HIV	Iot & wireless	Community	Effectiveness
		Healthcare-associated infections	non-specific	ICT	Hospital	Performance
			CLABSI	Simulation technology	Hospital	Effectiveness
		Other	Pelvic inflammatory disease	ICT	Hospital	Effectiveness
			Respiratory tract infections	Mobile App.	Multi-centre	Effectiveness
Nursing education	Continue training	Emerging Infectious	Ebola	Simulation technology	Department of Defense	Quality
			Ebola	Simulation technology	Simulation centre	Effectiveness
		Healthcare-associated infections	non-specific	E-learning	Hospital	Quality
			non-specific	E-learning	Multi-centre	Quality
			CLABSI	E-learning	Simulation centre	Quality
			CLABSI	Simulation technology	ICU	Quality
			Contact-related hais	E-learning	Paediatric	N/A
			Contact-related hais	Simulation technology	Nursing home	Quality
		Other	Antimicrobial Stewardship	E-learning	Multi-centre	Effectiveness
			Sepsis	Simulation technology	Simulation centre	N/A
	School training	Healthcare-associated infections	non-specific	Mobile App.	University Medical Centre	Effectiveness
		Other	Antimicrobial resistance	E-learning	University Medical Centre	Efficiency

(continued)

TABLE 7 (continued)

Nursing category	Nursing activity	Infection category	Infection disease	Technology category	Setting cat	Outcome
Nursing assessment	Assessment	Emerging Infectious	COVID-19	AI	Multi-centre	Efficiency
		Healthcare-associated infections	CLABSI	Sensor	Hospital	Quality
		Other	Urinary tract infection	Iot & wireless	Community	Performance
			Urinary tract infection	Mobile App.	Nursing home	Efficiency
	Recording	Healthcare-associated infections	non-specific	Iot & wireless	Infectious Diseases Ward	Efficiency
			SSIs	Sensor	N/A	Effectiveness

reducing HCWs burnout could be a new strategy to reduce HAIs (Galletta et al., 2016; Hermon et al., 2015; Rea et al., 2018, p. 1; Topal et al., 2019). In further quality improvement work, we may consider HCWs' mentation and their perceptions as a part of the quality improvement program to improve patient care.

4.1.4 | Nursing management

For decision support and decision-making, AI and ICT were frequently used for management. Four studies used ICT to develop a clinical decision support system to manage HAIs in emergency department, hospital and intensive care unit settings. In emergency department setting, studies were focussed on the efficacy of ICT for nursing staff to improve antimicrobial stewardship. Decision support should assist at different points of care and adapt to different professionals. To lower the blood culture contaminant rate, using ICT is an approach to increase HCWs self-awareness by informing nurses about the contamination rate in the patient ward; the results showed that it was an effective approach to decrease blood culture contaminants by nurses. In hospital and intensive care unit settings, two studies concluded that information systems improved nursing efficiency and patient safety significantly, particularly when nurses were enrolled for the design of information items (Cervero et al., 2019; Feretzakis et al., 2020; Lee et al., 2017; Ozkaynak et al., 2018; Qin et al., 2017).

The utilization of the AI bedside system in nursing management may optimize antibiotic dosing, and this approach has assisted antimicrobial stewardships and may reduce antimicrobial resistance; however, its effectiveness still needs more research evidence in clinical practice (Roggeveen et al., 2019). To manage the massive data in our daily clinical practice, filtering the appropriate information at the right moment with the right person may be a future trend in health care because the quantity of data is increasing. Using deep learning in the electronic healthcare record system could develop clinical decision support more efficiently in disease management, and certain models may reduce information overload for intensive care unit physicians (Kaji et al., 2019).

Patient management is a major nursing activity, including clinical follow-up, patient empowerment and patient education. For clinical follow-up, the IoT in a home-based, self-testing setting for HIV patient follow-up in real-time and e-consultation using smartphones was used. This method was feasible and acceptable for HIV patients; however, acceptability for clinical follow-up in the long term remains uncertain (Wray et al., 2017). Using smartphones may also assist in paediatric patient follow-up. After consultation, the use of smartphones affords clinical information and online consultation with parents; one study showed that the infection rate and duration of antibiotic use could be reduced (Lv et al., 2019). Additionally, the automated message texting system combined with the hospital information system was used in pelvic inflammatory disease patient follow-up; this method improved the short-term clinical follow-up and reduced the infection rate (Trent et al., 2019). According to these studies, the evidence of long-term follow-up and applications to other infectious diseases require further research.

Regarding patient empowerment, one study used a video system to assess the risk of HAIs. They demonstrated that enrolling patients in infection control programs could promote patient education about the risks of infection, improving the infection control program (Wyer et al., 2015). Moreover, to educate patients appropriately, high-fidelity simulation was used in one study to train the parents of paediatric patients for central-line daily care at home, and this approach improved home care quality in children with cancer (Heiser Rosenberg et al., 2017).

4.1.5 | Nursing education

The major research in nursing education is focussed on simulation-based training and e-learning.

Simulation technology is used frequently in skills training, such as personal protective equipment training and continued HCWs training. Two studies considered that high-fidelity simulation was effective in developing HCWs competency to face the Ebola virus epidemic (Abualenain & Al-Alawi, 2018; Delaney et al., 2016). Some results have shown that simulation-based training could improve central-line maintenance care and infection control practice to improve patient outcomes and safety (Barsuk et al., 2015; Holland, 2017). However, one study failed to demonstrate any impact on clinical performance in simulations after a classroom lecture training on sepsis management (Lighthall et al., 2016).

E-learning is used frequently in distance education in knowledge-based learning. To improve antimicrobial stewardship, one study showed that, during a limited period, this approach could significantly improve students' performance evaluated by simulating clinical practice. One study concluded that the e-learning method was more likely to improve knowledge on the clinical use of the antibiotic vancomycin among nurses, whereas traditional education was associated with improved knowledge among doctors (Gonzalez et al., 2016; Sikkens et al., 2018). To improve knowledge on HAIs prevention, two studies considered e-learning as a time-effective approach. Additionally, e-learning based on expert experience and an edutainment video is likely to be more effective to improve knowledge than the classic method (Labeau et al., 2016; Wolfensberger et al., 2019).

4.1.6 | Nursing assessment

In nursing assessment, technology trends are focussed on the IoT and sensors such as remote devices for automatic monitoring and measurement to record patients' vital signs and body liquid output continuously.

Two studies used the IoT in patient monitoring. Using a wireless Bluetooth ingestible sensor to assess body temperature in an infection environment, the study showed real-time remote control potentially saving nursing time and reducing unnecessary contact (Huang et al., 2020). Another study used remote point-of-care and wireless urinary tract screening to offer personalized monitoring and distance monitoring; however, a further clinical trial in clinical practice is needed ("A Community-Based IoT Personalized Wireless Healthcare Solution Trial," 2018). Sensors were used to assist in measuring the output rate and venous assessment. One study used a smart sensor to measure the surgical drain output and has the potential to save time, ease the pressure on nursing staff and reduce the SSIs rate (Duren & Boxel, 2017). A study using an ultrasound device for peripheral venous assessment that can assist nurses in reducing non-essential peripherally inserted central catheter and catheter failure observed significant cost savings (Reeves et al., 2017).

4.2 | Strengths and limitations

This review was conducted using a rigorous procedure and followed the standards of the methodology throughout the whole process to screen pertinent articles and achieve research questions (Arksey & O'Malley, 2005; Levac et al., 2010; Tricco et al., 2018). Although this review aimed to use research terms as wide as conceivable to retrieve all relevant articles, while restricting articles related to surgical robots or telehealth, we might have missed some relevant articles. To form a reasonable scope, the considered time frame was constrained to 6 years. This limitation might miss some meaningful studies; however, in the field of technology, we consider this period a rational restriction.

In general, studies with negative results are usually not published; thus, publication bias should be considered here. To avoid misunderstanding due to the translation, our search strategy was only focussed on articles published in English, which could be a limitation of this review. However, translation software tools have been developed with great progress in recent years, and most studies are published in English. Another limitation in this review could be geographic, although this review included studies from 23 different countries, yet most of these were conducted in developed countries, which could not overall the different educational background.

One challenge in this review is the grouping of technology categories. In some studies, several technologies could be used simultaneously. However, this review identified the main technology which is more dominant in each study to clarify the trends, a strategy that should be considered a limitation. However, two authors identified study characteristics and categories independently and checked the agreement after discussion to limit bias. Finally, due to the scoping review design of the study, an assessment of bias regarding the limitations of methodology or risk is usually not performed (Munn et al., 2018).

5 | CONCLUSIONS

This scoping review provides a map of the evidence of technology trends for nursing and infectious diseases. These technology trends include the IoT is often used in assessment areas, AI in prevention and control areas, ICT in the management area and simulation and e-learning in education. Additionally, the IoT was the most beneficial technology to improve nursing effectiveness and AI could improve nursing performance.

To obtain accurate data, the experiments required high HCWs' cooperation and participation over time. These requirements were challenges in clinical practice because of workload and stress. Maintaining a high participation rate is essential to avoid low participation and assess long-term experience, and several of the included studies enrolled patients or HCWs to participate in the development of the system and program design. User-driven development (user-centred design) might enhance HCW acceptance and may be the core concept and challenge in future research. Presently, technology is not only machine based but also requires human input.

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CONFLICT OF INTEREST

Authors declare no conflicts of interest.

AUTHOR CONTRIBUTION

All authors have agreed on the final version and meet at least one of the following criteria [recommended by the ICMJE (https://www.icmje.org/recommendations/)]: substantial contributions to conception and design, acquisition of data or analysis and interpretation of data; drafting the article or revising it critically for important intellectual content.

ETHICAL APPROVAL

As this was a scoping review, Research Ethics Committee approval was not required in this study.

DATA AVAILABILITY STATEMENT

All data generated or analysed during this study are included in this published article (and its supplementary information files).

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