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REVIEW

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Digital tools for post-discharge surveillance of surgical site infection

Camila Dalcól[1] | Judith Tanner[2] | Vanessa de Brito Poveda[1]

[1]University of São Paulo School of Nursing, São Paulo, Brazil

[2]University of Nottingham, Nottingham, UK

Correspondence
Vanessa de Brito Poveda, University of São Paulo School of Nursing, Av. Dr. Enéas de Carvalho Aguiar, 419, Cerqueira Cesar, CEP 05403-000 São Paulo, SP, Brazil.
Email: vbpoveda@usp.br

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Abstract

Aims: Conduct a scoping review on the development and use of digital tools for post-discharge surgical site infection surveillance.

Design: Scoping review.

Data Sources: Science Direct, PubMed, Embase, *Literatura Latino-Americana e do Caribe em Ciências da Saúde* and Cumulative Index to Nursing and Allied Health Literature were searched from 2013 to May 2022. Six intellectual property registries were reviewed from 2013 to 2022.

Review Methods: The review followed the Joanna Briggs Institute model, and included intellectual property records (applications, prototypes and software) and scientific articles published in any language on the development and/or testing of digital tools for post-discharge surveillance of surgical site infection among surgical patients aged 18 and over.

Results: One intellectual property record and 13 scientific articles were identified, covering 10 digital tools. The intellectual property record was developed and registered by a China educational institution in 2018. The majority of manuscripts were prospective cohort studies and randomized clinical trials, published between 2016 and 2022, and more than half were conducted in the United States. The population included adult patients undergoing cardiac, thoracic, vascular, abdominal, arthroplasty and caesarean surgery. The main functionalities of the digital tools were the previously prepared questionnaire, the attachment of a wound image, the integrated Web system and the evaluation of data by the health team, with post-discharge surgical site infection surveillance time between 14 and 30 days after surgery.

Conclusion: Digital tools show promise for the surveillance of surgical site infection, collaborating with the early detection of wound infection.

Implications for the Profession and/or Patient Care: Mobile technology was favourable for detecting surgical site infections, reducing unnecessary visits to the health service, and increasing patient satisfaction.

Impact: Technological advances in the health area open new perspectives for post-discharge surveillance of surgical site infection.

What is Already Known?

- There is underreporting of surgical site infections due to difficulties related to traditional methods of post-discharge surveillance.
- The use of digital tools within surgical site infection surveillance is increasing.

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- Benefits of using digital tools within surgical site infection surveillance have been reported.

What has this Study Added to our Knowledge?

- This scoping review is one of the first to analyse the development and use of digital tools for post-discharge surveillance of surgical site infection in different countries.
- The main functionalities of digital tools are: structured questionnaires; attachment of wound images; integrated web systems; and evaluation of data by professionals.
- The use of mobile technology is favourable for detecting surgical site infections with a reduction in costs from face-to-face consultations and increased patient satisfaction.

Where and on Whom will the Research have an Impact?

- Healthcare providers can successfully use digital tools for surgical site infection post-discharge surveillance.
- Remote monitoring can reduce unnecessary patient visits to healthcare facilities.
- Policy makers can study how to implement digital platforms for remote patient monitoring.

Reporting Method: PRISMA statement for Scoping Reviews (PRISMA-ScR).

Patient or Public Contribution: No patient or public contribution.

Trial and Protocol Registration: The study protocol was registered in the OSF (https://doi.org/10.17605/OSF.IO/BA8D6).

KEYWORDS

mobile applications, patient discharge, perioperative nursing, public health surveillance, surgical wound infection

1 | INTRODUCTION

Many high-income countries and some middle- to low-income countries have a national surgical site infection (SSI) surveillance programme (Russo et al., 2021). These programmes find the global proportion of surgical site infection is 9.9%. Over 60% of these infections occur after hospital discharge (Woelber et al., 2016), so being able to obtain post-discharge SSI surveillance data is increasingly important. However, post-discharge surveillance faces several challenges which can lead to underreported SSI cases (Clayphan et al., 2022). Many of the challenges relate to the burden of resources, such as the high cost of post-discharge follow-up or the amount of staff time required (Monahan et al., 2020). Other factors relating to access can be influenced by geography, economy or infrastructure (Russo et al., 2021; World Health Organization [WHO], 2018).

Developments in technology as well as the Covid-19 pandemic has led to the proliferation of digital tools to collect post-discharge SSI surveillance (Hutchings, 2020). Digital tools may offer some advantages over traditional wound follow-up. This scoping review will focus on the development and use of digital tools for post-discharge surveillance of surgical site infection.

2 | THE REVIEW

Although telephone calls remain the primary mechanism used in SSI post-discharge surveillance due to their availability and low cost, the growth from 2.2 billion mobile phones (82 per 100 inhabitants) in 2005 to more than 7 billion (>120 per 100 inhabitants) in 2015 (World Health Organization [WHO], 2016), and the continuous development of mHealth, need to be taken into account by health staff when planning healthcare.

MHealth is defined as using mobile devices for health practices, such as cell phones, monitoring devices, applications and personal digital assistants (PDAs). Providing technology for mobile communication is considered economically advantageous compared to face-to-face services, in addition to contributing to the quality of life of patients (Contractor et al., 2022; WHO, 2018).

The use of telehealth enables communication between the patient and the health service when separated by distance. It can occur synchronously, in real time, by telephone or video call or asynchronously, when a consultation or response is provided later, such as by text message or email (WHO, 2016).

New technologies are an opportunity to leverage SSI post-discharge detection and make this surveillance more consistent,

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using patient-generated health data captured through mHealth. Mobile tools for SSI surveillance allow the capture and analysis of information and images of surgical wounds after hospital discharge, helping professionals to diagnose and manage SSI (Sawyer et al., 2019).

The use of mHealth is a growing reality in several countries, with effective and satisfactory results for health professionals and patients. Factors favouring the use of mHealth include improved communication, enabling monitoring of a greater number of patients, aiding quality and safety review, early SSI diagnosis, reducing hospital readmission, as well as increasing self-care and reducing patient anxiety (Oliveira et al., 2022).

3 | AIM

This study aims to perform a scoping review on the development and use of digital tools for post-discharge surveillance of surgical site infection, summarize the tools' functionalities and identify gaps/strengths/weaknesses to guide future studies.

4 | METHOD

4.1 | Design

This scoping review was conducted following the JBI methodology and the recommendations of the PRISMA statement for Scoping Reviews (PRISMA-ScR) (Tricco et al., 2018). The JBI Scoping Review methodology allows for clarifying areas of knowledge and possible gaps, following five steps: identification of the research question; survey of relevant studies, considering the scope of the review; selection of studies; data mapping; and presentation of results (Peters et al., 2020).

The question was designed according to the PCC strategy: P) Population to be investigated (surgical patients); C) Concept (development and use of mobile application and/or tool); C) Context (Surgical site infection post-discharge surveillance). Thus, the research question was: What is the scientific and technological evidence for the development and use of applications or digital tools for post-discharge surveillance of surgical site infection?

The study protocol was registered with the Open Science Framework (OSF) (https://doi.org/10.17605/OSF.IO/BA8D6).

4.2 | Search methods

The following databases were searched; *Science Direct*, PubMed, *Embase*, Literatura Latino-Americana e do Caribe em Ciências da Saúde (LILACS), and the *Cumulative Index to Nursing and Allied Health Literature* (CINAHL), from 2013 to May 2022. In addition to scientific articles, to identify possible digital tools for SSI surveillance that are not present in scientific studies, intellectual property (IP) records from 2013 to May 2022 were analysed, from the Database of the National Institute of Industrial Property (*Banco de Dados do Instituto Nacional de Propriedade Industrial*—INPI), the European Patent Office (EPO), the World Intellectual Property Organization (WIPO), the United States Patent and Trademark Office (USPTO), ESpacenet and PatentInspiration. The reviewers contacted the authors of eligible studies to obtain additional information related to the findings.

The search for grey literature was based on selecting potentially relevant studies by consulting the references cited in the selected articles.

The terms or descriptors used for the search in the indexed databases were selected from the Medical Subject Headings (MESH) and from the Health Sciences Descriptors (DECS) using controlled and uncontrolled descriptors combined to guarantee a broad search (Table 1).

The following descriptors were used in the IP record databases: *cirurgia*/surgery, *paciente*/patient, *aplicativo móvel*/mobile application, *infecção*/infection, *vigilância*/surveillance, software, *controle*/control, *telemedicina*/telemedicine, *sistema de informação*/information system, *alta hospitalar*/hospital discharge, *pós*/post, *imagem*/image, mobile, application, surgical infection, postoperative wound, home monitoring, mobile health, mobile phone and smartphone.

Articles and records were selected according to the inclusion and exclusion criteria by reading titles and abstracts by two reviewers, and the selected materials were read in full. A third reviewer resolved disagreements between reviewers in the manuscript selection process.

4.3 | Inclusion and exclusion criteria

Intellectual property records related to the development of applications, prototypes and software linked to the detection of SSI among adult surgical patients and scientific articles published in any language on the development and/or testing of digital tools for post-discharge surveillance of SSI among surgical patients aged 18 and over, published in the last 10 years were included. This period was established due to the increase in mobile phone usage (WHO, 2016) and health apps from 2012, and the increased publishing of mHealth-targeted devices by companies, considering that 32% of all devices have been launched since early 2015 (R2G, 2016).

Review articles, letters to the reader, editorials, comments or abstracts presented at events and research and records related to surgical and/or postoperative care in general were excluded.

4.4 | Search outcome

Initially, 2978 scientific studies were identified in indexed databases and two manuscripts from the grey literature. Of these, 656 were duplicates, and 2297 were excluded after reading the title and abstract, leaving 13 articles. Additionally, 3441 intellectual property records were identified in the investigated databases, and after

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TABLE 1 Search strategies using controlled and uncontrolled descriptors (São Paulo, Brazil, 2022).

Database	Search strategy
Science Direct	(postoperative infection AND mobile application AND patient); (postoperative infection AND mobile phone); (Surgical Infection AND "mobile health"); ("Surgical Infection" AND surveillance); ("wound assessment" AND software AND surgery)
PubMed	(Mobile application) AND Surgical Infection AND ("last 10years"[PDat]); ((((("Surgical Wound Infection"[Mesh]) OR "Wound Infection"[Mesh] OR "Surgical site infection" OR "Surgical infection") AND ("Mobile Applications"[Mesh] OR "mHealth" OR "Mobile health" OR "Telemedicine" OR "Smartphone application" OR "Software"[Mesh]) OR "Software Design"[Mesh]) OR "Software Validation"[Mesh]) AND ("Cell phone" OR "Mobile phone" OR "Smartphone"); AND ((postoperative infection OR surgical infection)) AND (teleconsultation OR mobile application or Telemedicine)); (('post-operative infection')) AND ('Telemedicine' or 'teleconsultation' or 'home monitoring'))
Embase	('surgical infection'/exp OR 'infectious complication'/exp) AND 'mobile application'/exp); ('surgical infection'/exp OR 'wound infection'/exp OR 'rectum surgery'/exp OR 'wound management'/exp) AND 'mobile application'/exp); ('telemedicine'/exp OR 'mobile health application'/exp OR 'medical technology'/exp) AND ('surgical infection'/exp OR 'wound infection'/exp) AND ([english]/lim OR [portuguese]/lim OR [panish]/lim) AND ([embase]/lim OR [medline]/lim OR [pubmed-not-medline]/lim) AND [2010–2019]/py); ('postoperative infection'/exp OR 'surgical infection'/exp OR 'surveillance'/exp) AND ('medical technology'/exp OR 'teleconsultation'/exp OR 'mobile application'/exp) AND ([english]/lim OR [portuguese]/lim OR [panish]/lim) AND [2010–2019]/py; ('software'/exp OR 'image analysis'/exp) AND ('surgical infection'/exp OR 'postoperative infection'/exp) AND 'surveillance' AND ([english]/lim OR [portuguese]/lim OR [panish]/lim) AND [2010–2019]/py
Lilacs	(tw:("infeccao do sitio cirurgico" or "infeccao da ferida cirurgica" or "controle de infeccao" or "infeccao da ferida operatoria" or "infeccao da ferida pos-operatoria")) AND (tw:("Software" or "Teleconsulta" or "Fotografia" or "Sistema de Informação")) AND (tw:("vigilancia" or "controle de infeccao" or "monitoramento")) AND (tw:("Aplicativos móveis" or "Telemedicina" or "Dispositivo móvel" or "Telefone móvel" or "tecnologia móvel"))
CINAHL	(Surgical Infection or Wound Infection) AND (mobile applications or apps or mobile apps or smartphone) AND (telemedicine OR mobile health application OR medical technology) AND (surgical infection OR wound infection); (Surgical Wound Infection OR Surgical site infection OR Surgical infection) AND (Mobile Applications OR mHealth OR Mobile health OR Telemedicine OR Smartphone application OR Software OR Software Design); (software OR image analysis) AND (surgical infection OR postoperative infection) AND surveillance

Source: Elaborated by the authors.

reading the titles and abstracts, seven were selected for complete analysis. Six of these were excluded for not meeting the inclusion criteria, resulting in one intellectual property record being included in the study. The excluded scientific studies and intellectual properties did not answer the research question or meet the inclusion criteria, as they did not test the digital tool for detecting or monitoring SSI and addressed topics such as application development costs or tools directed to general postoperative care. The search and selection process is reported in Figure 1.

4.5 | Quality appraisal

No formal quality appraisal was undertaken, as the primary focus of the review was to provide an overview of the current situation rather than drawing conclusions from the included papers.

4.6 | Data abstraction

IP data were organized according to registration, title and summary of intellectual property, country of origin, international classification, name of investors, filing date, publication date, citations of other patents/intellectual property and software records and generation of scientific invention articles related to software patents or registrations.

The manuscripts were organized according to the title, authors, year, study type/design, publication journal, country, type of application, objective, method, population and sample, technology developed, technology functions, main results, conclusion, limitations, potential and suggestions for future research.

4.7 | Synthesis

Due to the heterogeneity of the studies included in this review, the synthesis of the included studies was qualitative, with results presented in tables and figures. Findings were categorized into two key themes: digital tools functionalities and usability, and advances, limitations and future projections.

5 | RESULTS

5.1 | Studies characterization

Thirteen scientific studies and one intellectual property record met the inclusion criteria, identifying 10 digital tools for post-discharge surveillance of SSIs (Figure 1). Table 2 provides the following details for the included studies: authorship, year of publication, origin, type of study, objective, population, sample and tool used. All 13 included studies were published in English and

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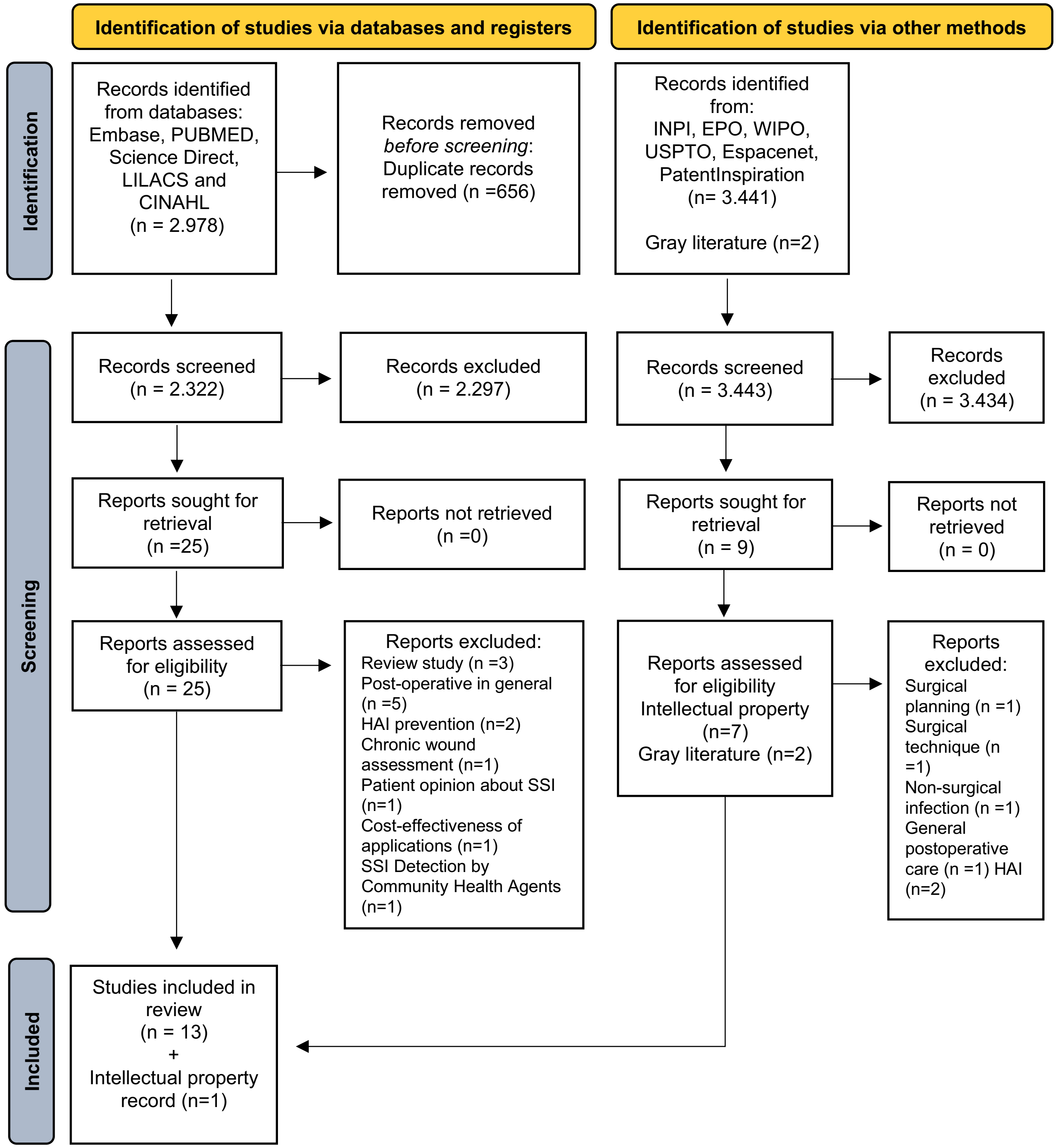

FIGURE 1 PRISMA flowchart of the study search and selection process (São Paulo, 2022). *Source*: Prepared by the authors according to PRISMA (Tricco et al., 2018).

conducted in high-income countries, with seven from the United States of America (USA). Most studies used a prospective cohort design although there were three randomized trials. All studies, except one, included adult patients only, and involved a range of different surgical specialities. Sample sizes ranged from six to 1434 patients.

Publications included in this review are concentrated from 2016 onwards, with peaks in 2017 and 2019 (Figure 2).

The IP was produced by a Chinese educational institution and was a risk assessment system that comprised three modules encompassing patient data, risk score and risk of surgical site infection (Table 3).

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TABLE 2 Characteristics of selected studies according to authors, year, origin, study type, objective, population, sample and the digital tool (Sao Paulo, 2022).

Authors/year	Origin	Type of study	Main objective	Sample (no. sample)	Digital tool
Gunter et al. (2016)	USA	Qualitative	Verify the usability of the application with surgical patients	Vascular surgery (9)	WoundCheck
Sanger et al. (2016)	USA	Qualitative	Verify agreements and conflicts about the use of the application by patients and providers	Patients (13), multidisciplinary team (11) and patient advocates (6)	mPOWEr
Castillo et al. (2017)	Canada	Prospective cohort	Verify the viability of the application	Caesarean (105)	How2trak
Evans & Lober (2017)	USA	Prospective cohort	Verify how the monitoring of surgical patients is carried out through the application	Surgical patients (54)	mPOWEr
Fernandes-Taylor et al. (2017)	USA	Prospective cohort protocol	Verify adherence and satisfaction of patients and caregivers with the use of the application	Patients (vascular surgery) (40) and caregivers (20)	WoundCheck
Mousa et al. (2017)	USA	Randomized clinical trial protocol	Identify hospital readmission and surgical site infection	Vascular surgery (200)	Enform telehealth
Gunter et al. (2018)	USA	Prospective cohort	Verify adherence and satisfaction with the use of the application by surgical patients	Vascular surgery (47)	WoundCheck
McLean et al. (2019)	United Kingdom	Randomized clinical trial protocol	Identify time to diagnosis of surgical site infection	Abdominal (emergency) (500)	Tracking wound infection with smartphone technology (TWIST) by RedCap
Scheper et al. (2019)	Netherlands	Prospective cohort	Identify ease of use and usefulness of the application	Arthroplasty (69)	Woundzorg
Zhang et al. (2019)	USA	Retrospective cohort	Evaluate the use of a digital platform for monitoring the surgical incision	Hip arthroplasty (1.434)	Plataforma Force Therapeutics
Ohr et al. (2021)	Australia	Prospective study protocol	Evaluate the effectiveness of the SSI surveillance system	Caesarean (700)	HealthTracker
McLean et al. (2021)	United Kingdom	Randomized clinical trial	Identify time to diagnosis of surgical site infection	Abdominal (emergency) (492)	Tracking wound infection with smartphone technology (TWIST) by RedCap
Alwis et al. (2022)	England	Cross sectional study	Comparing different post-discharge surveillance strategies	Cardiac and Thoracic—Adult and paediatric (1.432)	Isla

Abbreviation: SSI, surgical site infection.

Source: Prepared by the authors.

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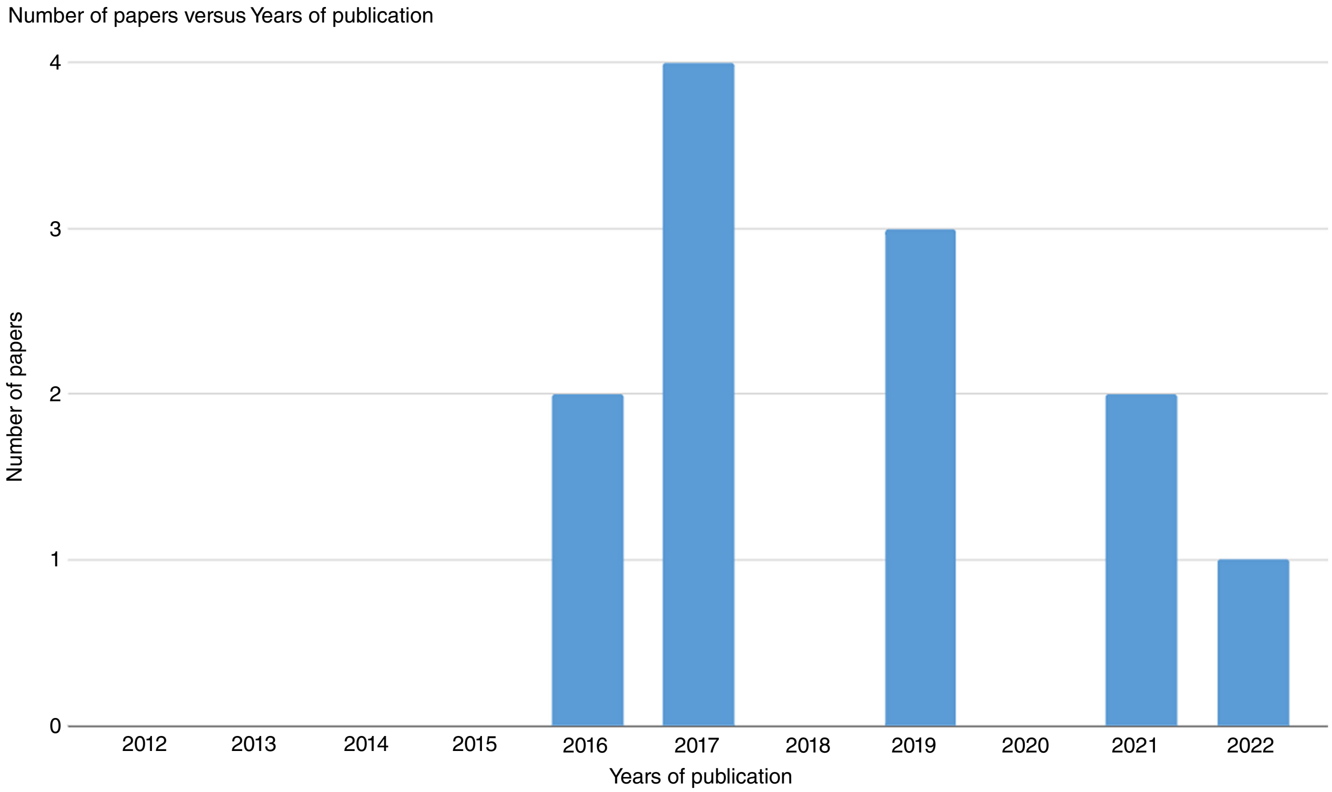

FIGURE 2 Number of articles according to the year of publication (Sao Paulo, 2022). *Source*: Prepared by the authors.

TABLE 3 Characteristics of the intellectual property record included in the study (São Paulo, Brazil, 2022).

Searched database	Patent number	Year	Title	Country	Depositor	Authors
Espacenet	CN108922620A	2018	Risk assessment system for surgical site infection	China	UNIV SOUTH CHINA	Xingxing C; Qidan D; Li L; Gaowen O; Yuan T.

Source: Elaborated by the authors.

5.2 | Digital tools functionalities and usability

Table 4 shows the name, type and SSI diagnostic criteria of the digital tools, postoperative follow-up period and categorization of the evaluators.

All 10 evaluated tools featured questionnaires that addressed clinical and surgical aspects, signs and symptoms related to the surgical wound, requiring yes or no responses, the attachment of a wound image and the use of a web platform for data (Alwis, 2022; Castillo et al., 2017; Evans & Lober, 2017; Fernandes-Taylor et al., 2017; Gunter et al., 2016, 2018; McLean et al., 2019, 2021; Mousa et al., 2017; Ohr et al., 2021; Sanger et al., 2016; Scheper et al., 2019; Zhang et al., 2019).

With respect to detecting SSIs through mobile technology, 67% of the studies addressed this outcome through images and questionnaire responses (Alwis, 2022; Castillo et al., 2017; Evans & Lober, 2017; Gunter et al., 2018; McLean et al., 2021; Ohr et al., 2021; Scheper et al., 2019; Zhang et al., 2019).

Some applications offered the exchange of instant messages between professionals and patients to provide advice and schedule clinical consultations (Evans & Lober, 2017; McLean et al., 2019; R2G, 2016; Sanger et al., 2016; Scheper et al., 2019; Zhang et al., 2019). Furthermore, some applications sent automatic notifications based on recorded information, such as checking body temperature or contacting a general practitioner or responsible physician (McLean et al., 2019; Scheper et al., 2019).

Other features offered were the use of devices to check the patient's vital signs, automatically sending the results via Bluetooth to the device used by the patient (Mousa et al., 2017); a satisfaction survey throughout the follow-up (Mousa et al., 2017); risk classification of patients after data analysis by a clinical researcher (Mousa et al., 2017); or a daily risk score based on questionnaires which issued high-risk alerts (Scheper et al., 2019).

In addition to SSI detection (Castillo et al., 2017; Evans & Lober, 2017; Fernandes-Taylor et al., 2017; Gunter et al., 2018; McLean et al., 2019; Mousa et al., 2017; Scheper et al., 2019), other

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TABLE 4 Characteristics of digital tools in relation to the sample, diagnostic criteria, follow-up time and qualification of evaluators (Sao Paulo, 2022).

Name of digital tool	Type	Diagnostic criteria for SSI	Communication	Postoperative follow-up period	Tool evaluators
Enform telehealth (Mousa et al., 2017)	Mobile application	Fever, erythema, discharge, dehiscence, scarring and pain	Blended (Asynchronous + Synchronous, by phone call if infection)	30 days	Nurses and physicians
How2trak (Castillo et al., 2017)	Mobile application	Self-reported signs and symptoms of infection	Asynchronous	30 days	NI
mPOWEr (Evans & Lober 2017; Sanger et al., 2016)	Mobile application	Fever, pain, fluid leakage, fluid colour	Asynchronous	NI	NI
Plataforma Force Therapeutics (Zhang et al., 2019)	Digital platform accessed by link	NI	Asynchronous	26 days	Orthopaedists
Tracking wound infection with smartphone technology (TWIST) (McLean et al., 2019, 2021)	Digital platform accessed by a link	Classification Criteria (CDC) and ASEPSIS Model	Synchronous	30 days	Experienced clinician (surgical or consultant)
WoundCheck (Fernandes-Taylor et al., 2017, Gunter et al., 2016; 2018)	Mobile application	Fever, use of medication for pain, erythema, oedema, odour and secretion, colour and dressing change	Blended (Asynchronous + Synchronous, by phone call if infection)	14 days	Nurses or physicians
Woundzorg (Scheper et al., 2019)	Mobile application	Redness, pain, wound leakage, fever	Asynchronous	30 days	Physicians
HealthTracker (Ohr et al., 2021)	Digital platform accessed by a link	NI	Asynchronous	30 days	Nurses and physicians
Isla (Alwis et al., 2022)	Digital platform accessed by a link	2013 Classification Criteria (CDC)	Asynchronous	30 days	Nurses and physicians[a]

Abbreviations: NI, not informed; SSI, surgical site infection.

[a]Response obtained by authors' primary study.

Source: Prepared by the authors.

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outcomes were also investigated such as hospital readmission (Fernandes-Taylor et al., 2017; Gunter et al., 2018; Mousa et al., 2017), patient characteristics (Zhang et al., 2019), agreements and conflicts between patients and application providers (Sanger et al., 2016), patient compliance and satisfaction (Gunter et al., 2018; McLean et al., 2021), frequency of access to the platform (Alwis, 2022; Scheper et al., 2019; Zhang et al., 2019), prevention of infection-associated morbidity and mortality (Fernandes-Taylor et al., 2017), wound monitoring (Fernandes-Taylor et al., 2017), feasibility of use (Castillo et al., 2017; Scheper et al., 2019), associated predisposing factors (Castillo et al., 2017), use of medical service or contact with surgical nurse (McLean et al., 2019, 2021; Scheper et al., 2019) and the agreement between the result reported by the patient and the physician (Scheper et al., 2019).

Considering patient access to mobile technology, 69% of patients logged into the platform at least once (Zhang et al., 2019), 59.4% used the application until the 30th day (Scheper et al., 2019), 48% sent images every 14 days (Gunter et al., 2018), 55% of the images were sent in the first 2 weeks (Zhang et al., 2019), 45% of the patients sent at least one photo and 43% of patients sent photos until the 30th day (Castillo et al., 2017). A digital SSI surveillance tool that used a web link sent via a text message achieved a response rate of 84.5% (Alwis, 2022).

Two studies assessed usability with averages of 87.2 (Gunter et al., 2016) and 83.3 (Gunter et al., 2018) on a scale of zero to 100, respectively, considered good in both studies. The average score for ease of use on a Likert scale from 1 to 5 was 4.2, and the perceived utility was 4.1 (Scheper et al., 2019).

The most cited concerns about the use of the application to detect SSI were the confidentiality of patient information and checking the data by the service team with feedback to the patient (Gunter et al., 2016).

In addition, the training time for using the application ranged from 9.7 to 16.9 min (Gunter et al., 2016, 2018), and the average time taken by patients for data completion was 5 min (Gunter et al., 2016). Even after training, 44% of the patients needed guidance from a research team member or staff member to complete the application, highlighting the difficulty in capturing the digital image of the wound (Gunter et al., 2016). Four studies evaluated patient satisfaction, and the perception was positive in all analyses (Evans & Lober, 2017; Gunter et al., 2016, 2018; Scheper et al., 2019).

5.3 | Advances, limitations and future projections

Table 5 shows the pattern, advances, gaps, evidence for the practice and recommendations for future research according to the PAGER framework for improving the quality of scoping review (Bradbury-Jones et al., 2022).

The main limitations of the included studies were small sample sizes (Gunter et al., 2016, 2018; Sanger et al., 2016), lack of comparison between groups of patients (Fernandes-Taylor et al., 2017; Zhang et al., 2019), patients of only one medical speciality (Mousa et al., 2017), performed in a single health service (Fernandes-Taylor et al., 2017; Sanger et al., 2016), SSI assessment by only one clinical professional (McLean et al., 2021), low patient response rates (McLean et al., 2021) and convenience sampling the participating hospital sites (Alwis, 2022).

The authors highlighted suggestions for improvement in the development of mobile technologies such as: including spaces for patient comments; issuing a message to the patient once their data has been evaluated; larger randomized studies of cost-effectiveness (Gunter et al., 2016); integration between data generated by patients with existing hospital systems (Sanger et al., 2016); testing the application on populations with different sociodemographic or cultural characteristics (Gunter et al., 2016); and training in the use of the application by nurses (Gunter et al., 2016).

6 | DISCUSSION

Although the COVID-19 pandemic caused numerous health, social and economic consequences, it has opened opportunities for digital health interventions and the development and use of mHealth, eHealth or telemedicine, and pointed to a new way of healthcare assistance (Getachew et al., 2023).

The identified digital tools were tested among patients of different surgical specialities, and the main functionalities were the previously prepared questionnaire, the attachment of a wound image, the integrated Web system, and the evaluation of data by the health team, with post-discharge SSI surveillance period between 14 and 30 days after surgery.

Thus, the digital tools applied synchronous, asynchronous or blended telemedicine, such as a health professional evaluating the responses and established contact by phone (Gunter et al., 2018) and face-to-face evaluation (McLean et al., 2019), and even completely asynchronous assessment tools, achieving high patient satisfaction (Evans & Lober, 2017; Gunter et al., 2016, 2018; Scheper et al., 2019).

Technological advances allied to healthcare can contribute to detecting SSIs by providing patients with the means to monitor and share their clinical and surgical conditions with health professionals, thus improving patient-professional communication after hospital discharge (Ke et al., 2017).

For example, a randomized clinical trial conducted with 492 surgical patients compared smartphone use with routine care for SSI surveillance for 30 days after hospital discharge. In total, 8.3% of the patients developed surgical site infections, with no significant difference between the groups. The median time to SSI detection was 9.3 days in the smartphone group and 11.8 days in the routine care group. Patients followed up by smartphone reported a significantly more positive experience concerning waiting time, ease of access to counselling, and quality of counselling received (McLean et al., 2021).

Thus, patients who receive postoperative follow-up remotely via smartphones are 3.7 times more likely to be diagnosed with SSI in the first seven postoperative days, leading to a significant reduction in the frequency of attendance at community health services ($p = .030$) and better experiences in accessing care ($p = .013$) (McLean et al., 2021).

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TABLE 5 PAGER framework of scoping review (São Paulo, Brazil, 2022).

Pattern	Advances	Gaps	Evidence for practice	Research recommendations
Validation of tools (Usability, feasibility, ease of use and perceived utility) (Castillo et al., 2017; Gunter et al., 2016; Scheper et al., 2019)	Adult surgical patients demonstrate good viability, usability, usefulness and ease of use of digital tools for post-discharge surveillance of SSI.	Studies with reduced samples and focus on only a few surgical specialities. Development of digital tools incompatible with the Android system.	Digital tools have good acceptance of use among adult patients for postoperative follow-up.	Methodological standardization regarding the usability tests of health applications, investment in larger samples, various specialities and different age groups. Construction of health applications compatible with Android and IOS.
Strategy of Monitoring/Surveillance for SSI detection (Evans & Lober 2017; Fernandes-Taylor et al., 2017; McLean et al., 2019, 2021; Mousa et al., 2017; Ohr et al., 2021; Zhang et al., 2019)	Active surveillance of SSI through digital tools improves early detection of SSI and avoids unnecessary visits to health services. The use of surgical wound images showed high specificity for the detection of SSI.	Studies conducted with small samples, in a single speciality, with only one evaluator, usually a physician.	Active surveillance of SSI through digital tools is beneficial for early treatment and reduction of hospital readmission of patients. The adherence of patients, professionals and health institutions to digital tools contribute to detecting SSI.	Future studies should analyse digital tools with larger samples of different specialities and age groups, based on multidisciplinary approaches (including physicians and nurses) in the postoperative follow-up. Studies enhancement of semi-automatic evaluation of surgical wound image, aiming to reduce the time detection of SSI.
Adherence and satisfaction (Alwis et al., 2022; Gunter et al., 2018)	Surgical patients demonstrate high satisfaction and moderate adherence to using digital tools to monitor SSI.	The scarcity of randomized clinical trials, limited sample size and surgical specialities analysed	Patients demonstrate satisfaction with digital tools, although adherence could be a problem.	Future randomized clinical trials may investigate large samples of patients with different ages, ethnicities, social classes and diverse surgical specialities. It is necessary to invest in training and awareness about the use of digital tools. Patient training by nurses can increase adherence to digital tools for monitoring SSI.

Abbreviation: SSI, surgical site infection.

Source: Elaborated by the authors.

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The perception of mHealth shared by patients emphasizes the ease, convenience, absence of need for face-to-face consultation, feeling of security and feeling of connectivity to the health service (Gupta et al., 2023; Roess, 2017). However, possible problems can be faced, such as weaknesses in clinical evaluation, network connection, communication, diagnosis and clinical investigation, and digitally illiterate patients (Gupta et al., 2023).

The mHealth tools identified in this study enabled monitoring of the signs and symptoms of SSI, in addition to enabling wound analysis through visualization of images attached by patients. When analysed together, these data help in the early detection of SSI (Ke et al., 2017) and involve patients in their self-care, contributing to the quality of patient recovery (Semple et al., 2015).

Evidence indicates that surgical wound images sent by patients via mobile phones enable reliable decisions made by health professionals regarding SSI diagnosis and are similar to face-to-face assessments. Sending images and collecting supplementary information on symptoms improve the sensitivity of monitoring post-surgical wounds. Thus, remote monitoring can prevent unnecessary visits to the doctor's office or even optimize home visits by nurses (Totty et al., 2018; Wiseman et al., 2015).

A recent study evaluated 53 wounds, in person and through photographs, analysed by physicians and nurses using the ASEPSIS scale to identify the presence of SSI, showed an agreement greater than 85% between the photograph and the clinical reviewers in all categories, except for erythema. The specificity of the photographic review for the diagnosis of SSI was 90%, and strong reliability was found among reviewers, pointing to a path of postoperative follow-up avoiding unnecessary visits to health services (Totty et al., 2018).

A recent study developed a standardized and optimized method for patients to capture images of their wounds and considered that 96.1% of the images were sufficient to assess a possible SSI. The 21 instructions advise on the importance of lighting, absence of shadows, wound cleaning before the picture, maintaining the anatomical position, using a millimetre ruler to measure the wound, and framing and distance, among others (Macefield et al., 2023).

The National Wound Care Strategy Program (NWCSP) recently published practical recommendations for using digital images in wound care, reinforcing the importance of quality imaging in patient clinical assessment and care efficiency, and developing future innovations such as artificial intelligence (NWCSP, 2021).

The studies included in this scoping review showed good usability, ease of use and patient satisfaction in using digital tools for SSI surveillance. A study analysed the willingness of patients and caregivers to use mobile technology to monitor their health status and demonstrated that: all were willing to answer questions about their health status; 80% of patients had a cell phone; 92% were willing to photograph and send images of the surgical wound and 90% had help with doing this (Wiseman et al., 2015).

Another study with 122 patients undergoing arthroscopic meniscectomy surgery showed that patient satisfaction with in-person postoperative care is equivalent to telemedicine follow-up. There were no significant differences between the groups in terms of complications. In addition, the authors concluded that remote monitoring should be considered a reasonable alternative to the traditional in-office modality (Herrero et al., 2021).

Despite the high level of satisfaction, patient adherence to digital tools varies between 43% and 59.4% (Castillo et al., 2017; Gunter et al., 2018; Scheper et al., 2019; Zhang et al., 2019). It is worth considering that access to digital tools depends on the patient having a mobile phone and knowing how to handle it. Nurses must also train patients and caregivers to use digital tools to increase adherence.

This scoping review represents an advance on a previous review study that identified the use of mobile apps and other forms of telemedicine applications for SSI detection after discharge and general postoperative care, as the previous review focused only on products developed in English and did not include IP records (Evans et al., 2019). Also, the present scoping review included seven new tools that provide SSI post-discharge surveillance, discussing their functionalities, post-discharge surveillance period, diagnosis criteria, advances and gaps of knowledge.

The wound surveillance smartphone app is an acceptable and important resource for interdisciplinary work, with the potential to improve patient-professional communication and the readiness of patients and providers to implement remote wound monitoring to identify potential SSIs (Sreedharan et al., 2022).

In short, an SSI surveillance protocol based on mHealth with the use of digital photos can improve monitoring of patients who develop complications from the surgical wound after discharge, considering that the success of this initiative depends on the involvement and involvement disposition of patients and caregivers (Wiseman et al., 2015).

Thus, the simultaneous involvement of technological and human resources for SSI surveillance is essential. This collaboration between communication and information technology professionals and health professionals, from the software development process to computerized systems and their evaluation, makes infection surveillance systems more effective (Lavallee et al., 2019).

As a limitation, it is challenging to reach the digital tools registered in IP databases if they do not have standardized search systems and there is a lack of information in the IP register. Additionally, the majority of evidence in this review on mHealth implementation came from prospective cohort studies, with just one randomized clinical trial and two randomized clinical trial protocols. Future studies could use high-quality randomized designs.

All the included studies were carried out in countries with high economic and social development and did not address challenges specific to middle- and low-income countries.

7 | CONCLUSION

The use of digital tools to facilitate SSI post-discharge surveillance is a rapidly developing area. This scoping review takes a first step in exploring this area by providing an overview of the tools, their functionalities and their emerging strengths and weaknesses. Evaluations

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to date are from experimental studies and more of these data are required to further explore strengths and weaknesses. However, as digital surveillance tools become embedded within usual clinical practice, new areas to explore will likely emerge. These may include, for example, the potential contribution of artificial intelligence, or validating this new surveillance method. This is an exciting time to participate in the rise of digital tools within SSI surveillance.

AUTHOR CONTRIBUTIONS

Made substantial contributions to conception and design, or acquisition of data, or analysis and interpretation of data; CD; VBP. Involved in drafting the manuscript or revising it critically for important intellectual content; CD; JT; VBP. Given final approval of the version to be published. Each author should have participated sufficiently in the work to take public responsibility for appropriate portions of the content; CD; JT; VBP. Agreed to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved. CD; JT; VBP.

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CONFLICT OF INTEREST STATEMENT

The authors declare no conflicts of interest.

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DATA AVAILABILITY STATEMENT

Data available on request from the authors.

ORCID

Camila Dalcól https://orcid.org/0000-0002-6224-0582
Judith Tanner https://orcid.org/0000-0003-0023-3149
Vanessa de Brito Poveda https://orcid.org/0000-0002-5839-7253

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