ORIGINAL RESEARCH

Candida auris: What literature exists to inform control of outbreaks in healthcare settings?

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ABSTRACT

Background: *Candida auris* (*C. auris*) has been identified as an emerging pathogen of interest in healthcare settings. Its resistance to antimicrobials, high mortality rates, ability to persist in the environment and increasing instances of outbreaks in healthcare settings constitute major concerns among healthcare practitioners across the globe. To address concerns regarding preventing transmission of *C. auris*, the Public Health Agency of Canada (PHAC) conducted a literature review to inform guidance for the infection prevention and control of *C. auris* in hospitals and long-term care facilities (LTC).

Methods: Electronic databases were searched to identify peer-reviewed evidence published between database inception until September 7, 2023. Peer-reviewed primary evidence and literature reviews, in English or French, reporting on infection prevention and control (IPC) practices put into place to prevent transmission of *C. auris* in healthcare settings were eligible for inclusion. Title and abstract screening, full-text review, critical appraisal, and data extraction processes were performed by two reviewers using DistillerSR systematic review software and the PHAC Infection Prevention and Control Critical Appraisal Toolkit. A scan of grey literature was also conducted to inform the review.

Results: Thirty-two articles of medium- to high-quality detailing *C. auris* IPC were included in the review. Settings reporting no transmission beyond the index case were more likely to report the use of risk-factor-based screening, private accommodation with dedicated toileting facilities, the use of personal protective equipment (PPE) consisting of gown and gloves at all times and the application of no-touch cleaners and disinfectants.

Conclusion: Multiple IPC interventions appear to be effective at minimizing transmission. However, determining effectiveness is challenging due to variability in intervention reporting and due to the lack of understanding of *C. auris* burdens before and after their implementation. Increased vigilance with screening and reporting would be advisable, and future work would benefit from multi-centre comparison of interventions using prevalence data.

KEYWORDS
Candida auris, outbreak, transmission, healthcare, hospital, long-term care, infection prevention and control

INTRODUCTION

Candida auris (*C. auris*) has been identified as a pathogen of concern and a growing threat in healthcare settings globally. *C. auris* is an antimicrobial-resistant organism (ARO) that is often resistant to multiple classes of antifungals, which can limit the effectiveness of available treatments (Chen *et al.*, 2020). It is also notable for its ability to cause invasive infections with high mortality (>40%) (Chen *et al.*, 2020). Once *C. auris* becomes established in a healthcare environment, it can be difficult to eradicate and can lead to outbreaks (Eyre *et al.* 2018)

C. auris can become resistant to all available antifungal drugs (Carolus *et al.*, 2021; Burrack *et al.*, 2022), persist on surfaces and multi-use equipment for extended periods of time (Welsh *et al.*, 2017; Biswal *et al.*, 2017; Abdolrasouli *et al.*, 2017), extensively contaminate healthcare environments (Adams *et al.*, 2018; Kumar *et al.*, 2019; Ruiz-Gaitan *et al.*, 2019; Eyre *et al.*, 2018; Patterson *et al.*, 2021), and be resistant to quaternary ammonium-based hospital disinfectants (Cadnum *et al.*, 2017; Heaney *et al.*, 2020). Some of the most prevalent reported risk factors for *C. auris* colonization and infection include: prolonged exposure to broad-spectrum antibiotics (Bougnoux *et al.*, 2018; Cortegiani *et al.*, 2018; de Cassia Orlandi *et al.*, 2018; Sarma *et al.*, 2017), indwelling medical devices (Bougnoux *et al.*, 2018; Cortegiani *et al.*, 2018; de Cassia Orlandi *et al.*, 2018; Sarma *et al.*, 2017), diabetes mellitus (Bougnoux *et al.*, 2018; Cortegiani *et al.*, 2018; de Cassia Orlandi *et al.*, 2018; Sarma *et al.*, 2017; Taori *et al.*, 2019), prolonged intensive care unit (ICU) hospitalization (Bougnoux *et al.*, 2018; Cortegiani *et al.*, 2018; de Cassia Orlandi *et al.*, 2018; Sarma *et al.*, 2017; Taori *et al.*, 2019, Tsay *et al.*, 2018), haemodialysis (Bougnoux *et al.*, 2018; Cortegiani *et al.*, 2018; de Cassia Orlandi *et al.*, 2018; Sarma *et al.*, 2017; Taori *et al.*, 2019, Tsay *et al.*, 2018), immunocompromised patients

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(Bougnoux *et al.*, 2018; Cortegiani *et al.*, 2018; de Cassia Orlandi *et al.*, 2018; Sarma *et al.*, 2017; Taori *et al.*, 2019, Tsay *et al.*, 2018), admission to a hospital or long-term care (LTC) facility outside of Canada, and transfer from a healthcare facility with an ongoing *C. auris* outbreak.

In Canada, numerous jurisdictions have existing guidance specific to *C. auris*, as do a number of international organizations, such as the Centres for Disease Control and Prevention, World Health Organization and Public Health England. However, there is frequent jurisdictional variation in different settings (e.g., acute vs. LTC) and specific guidance, for example variations in risk factor-based screening, screening sites and laboratory identification methods.

Reports of *C. auris* cases and outbreaks in healthcare settings globally, including across North America, have increased in recent years (Garcia-Bustos *et al.*, 2021). Currently in Canada, *C. auris* is only reportable in the provinces of Alberta and British Columbia. From 2012 to 2023 a total of 53 *C. auris* cases had been reported to the Public Health Agency of Canada (PHAC), representing isolates for both colonized and infected cases submitted to the Agency voluntarily via the Canadian Nosocomial Surveillance Program (CNISP) and provincial/territorial reference laboratories, and in reportable provinces. The objective of this work was to identify and summarize *C. auris* infection prevention and control interventions (*C. auris* IPC) described in the literature to ultimately inform the development of guidance for *C. auris* in Canadian healthcare settings.

METHODS

Search strategy

A systematic review was conducted according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines (Page *et al.*, 2021). The search strategy was developed collaboratively by IPC experts and library information specialists. Population, Exposure, Intervention, Control and Outcomes (PEICO) criteria for the literature search are detailed in Table 1. Ovid MEDLINE, Embase, Global Health and Scopus bibliographic databases were searched for evidence published from inception up to September 7, 2023. In June 2023, a grey literature search of outbreak registries and IPC conference publications was completed. The reference lists of relevant literature reviews (n=20) were also scanned.

Study eligibility

The review aimed to inform guidance for Canada, focusing on countries with comparable healthcare settings and IPC practices. Eligible publications included primary evidence on *C. auris* IPC implemented in response to *C. auris* cases or transmission events in hospital or long-term care (LTC) settings in the following countries: Belgium, Canada, France, Germany, Italy, Japan, the Netherlands, Sweden, Switzerland, the United Kingdom, the United States, Australia, and New Zealand. Included evidence was restricted to English and French to ensure language comprehension during review. The primary outcomes of interest were the *C. auris* IPC interventions implemented and their effectiveness. News articles, editorials, commentaries,

Table 1: PICO search criteria for this review

Population	**Personnel:** Healthcare workers (HCW), physicians, surgeons, dentists, midwives, obstetricians/gynecologists, nurses, healthcare students/trainees, infected HCWs/students/trainees and their patients, clients, or residents. **Setting:** Healthcare, health care, acute care, hospital, clinic, intensive care (ICU), emergency room (ER), and long-term care (LTC).
Exposure	*Candida auris* or *C. auris*
Intervention	Infection prevention and control (IPC), intervention, isolation precautions, outbreak management, personal protective equipment (PPE), contact tracing, investigation.
Comparison	Not relevant at this time.
Outcome	Outbreak, cluster, transmission, transmission event, exposure, exposure event, case, infection.

opinion pieces, policy statements and government white papers lacking primary evidence on *C. auris* IPC were excluded. Research on *C. auris* species distribution, phylogeny, antifungal susceptibilities, molecular identification, clinical outcomes, or treatments were also excluded.

Study selection and data extraction

Following article de-duplication, title and abstract screening, full-text review, data extraction was performed in duplicate by reviewers (SE, HH, CP, TW) using DistillerSR and Microsoft Excel. Conflicts were reviewed and discussed among reviewers until consensus was reached. A total of 2,342 reports were identified, after removing duplicates, 987 reports were retained and were screened for eligibility. Reports were excluded if they did not report a *C. auris* case or transmission in healthcare settings (n=475), or if they were not from a selected country (n=254). The remaining 257 reports underwent full-text review. Reports were further excluded if they did not describe a *C. auris* intervention (n=110), if the study was a review (n=71), an abstract (n=35), or if the appraisal tool rated the study as having low-quality evidence (n=9). After review and quality appraisal, 32 reports were included in the data synthesis.

Evidence synthesis

Studies providing relevant evidence appraised as medium or high-quality, as described by PHAC (PHAC, 2014) were qualitatively synthesized to reflect the hierarchy of controls as described by PHAC (PHAC, 2016). Basic descriptive statistics (i.e., proportions) were used to compare the reporting frequency of various interventions.

Evidence quality appraisals

Evidence included in the narrative synthesis was critically appraised using PHAC's Infection Prevention and Control Guidelines Critical Appraisal Toolkit (CAT) (PHAC, 2014). Appraisals were completed in duplicate by four reviewers

(SE, HH, CP, TW). Conflicts were discussed among all reviewers until consensus was reached. Conference abstracts were excluded from the critical appraisals due to limited reporting of study details and methodologies.

RESULTS

Overview of included studies

PRISMA results can be found in Figure 1. Thirty-two reports were appraised as providing medium quality evidence on *C. auris* IPC implemented in response to *C. auris* cases and/or transmission and were captured within the narrative synthesis (Tables 2 and 3).

Sixteen of the included studies described events that occurred in the United States, followed by the United Kingdom (n=5), Italy (n=2), Canada (n=3), Germany (n=2), Australia (n=2), France (n=1) and Japan (n=1). Nineteen studies described IPC interventions implemented in response to *C. auris* transmission events, while the remaining 13 studies described IPC interventions where *C. auris* was limited to the index case (i.e., no transmission).

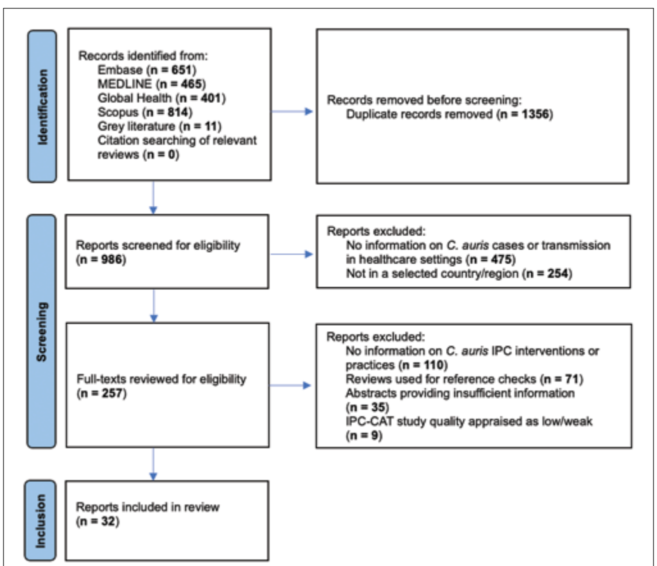

Figure 1: PRISMA flowchart of literature screening process.

Reports that detailed *C. auris* transmission events were more likely to include the use of multiple *C. auris* IPC interventions. Figure 2 shows the relative proportions of various IPC interventions described. In cases where no transmission was reported, authors were more likely to indicate the use of risk-factor-based screening, private accommodation with dedicated toileting facilities, the use of PPE consisting of gown and gloves, the use of contact precautions and the application of no-touch cleaners and disinfectants.

Engineering controls

Seventeen studies reported the use of some sort of private accommodation for *C. auris*-positive patients. Details about these accommodations, including the type of toileting facilities, were infrequently and inconsistently reported. Only one study specifically reported the use of "private toileting facilities" (Eckbo *et al.*, 2021). Twenty-four studies reported the use of contact precautions and isolation. No variations in isolation, such as use of higher-level precautions or restrictions to movement, were reported.

Administrative controls

Admission screening

Factors considered to warrant *C. auris* screening on admission were variable across reports. Some of the reported risk factors for screening admissions included international medical transfers (Patterson *et al.*, 2020), transfers from facilities with known *C. auris* transmission (Karmarkar *et al.*, 2021) and history of antifungal use (Osbourne-Townsend *et al.*, 2022).

Compliance monitoring

Multiple authors (n=12) reported utilizing auditing and/or compliance monitoring processes in response to cases of *C. auris*. These processes often targeted hand hygiene and environmental cleaning. Hand hygiene audits, the presence of alcohol-based hand sanitizer (ABHS) in and outside of patient rooms, verification of adequate cleaning and disinfection by a unit manager or fluorescent markers on high-touch surfaces was reported (Austin *et al.* 2022, de St Maurice *et al.*, 2023, Karmarkar *et al.*, 2021, Lesho *et al.*, 2018, Pacilli *et al.*, 2020, Patterson *et al.*, 2020, Prestel *et al.*, 2021, Reimer-McAtee *et al.*, 2021, Sticchi *et al.*, 2023, Taori *et al.*, 2019, Walits *et al.*, 2020,

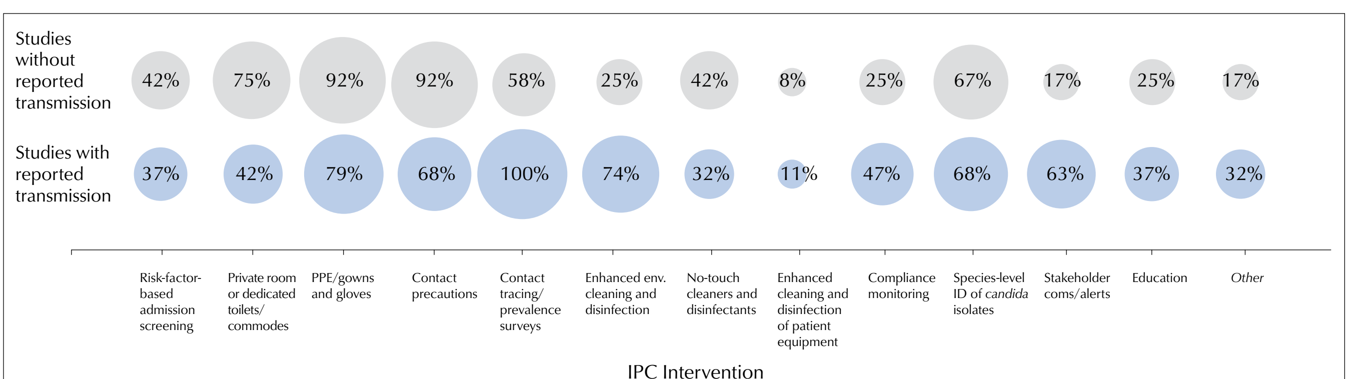

Figure 2: Proportional comparison of IPC interventions among studies reporting transmission vs. no transmission.

Table 2: Evidence summary of study overview, transmission factors and quality appraisal results

Author, Publication year	Publication type	Country	Study period	Factors linked to *C. auris* transmission	Event outcomes	Quality of study
Adams *et al.*, 2018	Primary journal article	U.S.	July 2017	Prolonged colonization of patients, environmental contamination, gaps in ABHR access, ineffective signage for, lack of education and access to PPE, ineffective cleaning and sterilization of shared medical equipment, household cleaners used in healthcare environments.	Outbreak ongoing at the time of publication	Medium
Alanio *et al.*, 2022	Primary journal article	France	January-February 2019	Missing admission screening.	Not reported	Medium
Austin *et al.*, 2022	Primary journal article	U.S.	May-December 2020	Hospital staff and services significantly stressed due to COVID-19 case surges and patients shared a semi-private room for one day.	Outbreak declared over	Medium
Brooks *et al.*, 2019	Primary journal article	U.S.	September 2018	Recent hospital stay in Kenya, Carbapenemase-producing organism (CPO) infection and colonization.	Not reported	Medium
Corcione *et al.*, 2022	Primary journal article	Italy	July 2021-March 2022	High rate of transferred patients from peripheral hospitals during the COVID-19 pandemic.	Not reported	Medium
de St Maurice *et al.*, 2023	Primary journal article	U.S.	October 2019-February 2022	Not reported	Not reported	Medium
Eckbo *et al.*, 2021	Primary journal article	Canada	2018	Previously unidentified *C. auris* case prior to implementation of precautions, overlapping ICU stays.	Outbreak declared over	Medium
Eyre *et al.*, 2018	Primary journal article	UK	February 2015-August 2017	Transmission linked to reusable medical equipment (temperature probes).	Outbreak ongoing at the time of publication	High
Hinrichs *et al.*, 2022	Primary journal article	Germany	2021	Temporary COVID-19 ICU and reusable medical equipment (laryngoscope blades).	Outbreak declared over	Medium
Karmarkar *et al.*, 2021	Primary journal article	U.S.	March-October 2019	Poor hand hygiene adherence, limited ABHR, and gaps in high-touch surfaces cleaning.	Outbreak ongoing at the time of publication	Medium
Lane *et al.*, 2018; Worth *et al.*, 2020*	Primary journal article	Australia	July-December 2018	Previous overseas hospitalization and transmission during a concurrent local hospital stay.	Not reported	Medium
Lesho *et al.*, 2018	Primary journal article	U.S.	June 2016-September 2017	Patient seems to have been screened but was not isolated until they tested positive for *C. auris*.	Not reported	Medium
McGann *et al.*, 2023	Primary journal article	U.S.	January 2022	Not reported	Not reported	Medium
O'Connor *et al.*, 2019	Primary journal article	UK	December 2018-January 2019	Ineffective contact screening.	Not reported	Medium
Ohashi *et al.*, 2023	Primary journal article	Japan	2020	International travel/hospitalization.	Not reported	Medium
Osbourne Townsend *et al.*, 2021	Primary journal article	Canada	April 2019-November 2020	International travel/hospital admission, indwelling devices, concurrent AROs.	Not reported	Medium

Table 2 (cont'd): Evidence summary of study overview, transmission factors and quality appraisal results

Author, Publication year	Publication type	Country	Study period	Factors linked to *C. auris* transmission	Event outcomes	Quality of study
Pacilli *et al.*, 2020	Primary journal article	U.S.	August 2016-December 2018	Patients co-colonized with CPO, lack of IPC staff, surveillance systems, available ABHR dispensers and PPE use, and inadequate compliance monitoring.	Outbreak ongoing at the time of publication	Medium
Patterson *et al.*, 2020	Primary journal article	UK	April 2019-November 2019	Direct ICU transfer from the Middle East and use of cloth lanyards.	Outbreak declared over	Medium
Prestel *et al.*, 2021	Primary journal article	U.S.	July-August 2020	Gaps in cleaning and poor hand hygiene adherence.	Outbreak declared over	Medium
Proctor *et al.*, 2021	Primary journal article	U.S.	January-April 2019	Ventilator-capable skilled nursing facility with endemic *C. auris*.	Not reported	High
Reimer-McAtee *et al.*, 2021	Primary journal article	U.S.	Not reported	Previous history of *C. auris* colonization in both cases.	Not reported	Medium
Rowlands *et al.*, 2023	Primary journal article	U.S.	November 2017-November 2019	Not reported	Not reported	Medium
Schelenz *et al.*, 2016	Primary journal article	UK	April 2015-July 2016	Not reported	Not reported	Medium
Schwartz *et al.*, 2017	Primary journal article	Canada	May 2017	Missing admission screening.	Not reported	N/A
Sexton *et al.*, 2021	Primary journal article	U.S.	October 2018	Not reported	Not reported	High
Steinmann *et al.*, 2021	Primary journal article	Germany	August 2019-April 2020	Not reported	Not reported	Medium
Sticchi *et al.*, 2023	Primary journal article	Italy	July 2019-December 2022	Unreported transfer of cases colonised with or infected by *C. auris* between facilities, and patients with common procedures in the same healthcare facility.	Not reported	Medium
Taori *et al.*, 2019	Primary journal article	UK	July 2016-February 2017	Lack of early identification and isolation of cases.	Not reported	Medium
Vu *et al.*, 2022	Primary journal article	U.S.	January 2020-December 2021	Missing admission screening.	Not reported	Medium
Walits *et al.*, 2020	Primary journal article	U.S.	2018	Not reported	Not reported	N/A
Waters *et al.*, 2023	Primary journal article	U.S.	October 2020-June 2021	Failure to implement appropriate contact precautions, poor hand hygiene adherence, and lack of infection preventionist.	Not reported	Medium

*Separate authors reporting on the same *C. auris* transmission event.
U.S., United States; UK, United Kingdom.

Waters *et al.*, 2023). Karmarkar *et al.* (2021) reported the used of environmental cleaning checklists in LTC settings to be effective at reducing *C. auris* transmissions. These checklists considered the type of disinfectant used, recommended wet contact time, procedures for mixing disinfectant solutions, PPE use, and environmental service staff cleaning protocols (Karmarkar *et al.*, 2021).

Education

The delivery of information and education on *C. auris* to patients, families, staff and physicians was a part of *C. auris* IPC in a number of reports (Corcione *et al.*, 2022, Eckbo *et al.*, 2021, Hinrichs *et al.*, 2022, Lesho *et al.*, 2018, McGann *et al.*, 2023, Osbourne Townsend *et al.*, 2021, Pacilli *et al.*, 2020, Sticchi *et al.*, 2023, Taori *et al.*, 2019, Walits *et al.*, 2020). This education was provided in multiple formats, such as one-on-one or group huddles among staff (Eckbo *et al.*, 2021), and written materials (e.g., educational posters) targeting patients and families (Corcione *et al.*, 2022). Topics addressed included proper hand hygiene, proper use of PPE, as well as compliance monitoring results (Pacilli *et al.*, 2020).

Stakeholder communications

Fourteen reports detailed the implementation of stakeholder communications. Communication strategies included alerts issued to health services or diagnostic laboratories (Adams *et al.*, 2018;

Table 3: Evidence summary of control measures targeting *C. auris* transmission

Author, Publication Year	Setting	Risk factor-based admission screening	Private room or dedicated toilets/ commodes for *C. auris* patients	Personal protective equipment/gowns and gloves	Contact precautions	Contact tracing/prevalence surveys	Enhanced environmental cleaning & disinfection	No-touch cleaners & disinfectants	Enhanced cleaning & disinfection of patient care equipment	Compliance monitoring (HH audits, environmental cleaning audits)	Species-level identification of *Candida* isolates	Stakeholder communications/ alerts	Education (staff, patients and visitors)	Other	Events reporting transmission to other patients or residents (Yes/No)
Adams *et al.*, 2018	Multiple (e.g., hospital + LTC)				✓	✓					✓	✓			Yes
Alanio *et al.*, 2022	Hospital			✓	✓	✓	✓				✓				Yes
Austin *et al.*, 2022	Multiple (e.g., hospital + LTC)		✓	✓	✓	✓	✓	✓		✓		✓	✓		Yes
Brooks *et al.*, 2019	Hospital	✓	✓	✓	✓	✓									No
Corcione *et al.*, 2022	Hospital		✓	✓	✓	✓	✓	✓					✓	✓	Yes
de St Maurice *et al.*, 2023	Hospital	✓		✓	✓	✓	✓	✓		✓	✓				Yes
Eckbo *et al.*, 2021	Hospital		✓	✓	✓	✓	✓				✓	✓	✓	✓	Yes
Eyre *et al.*, 2018	Hospital	✓		✓		✓	✓				✓	✓			Yes
Hinrichs *et al.*, 2022	Multiple (e.g., hospital + LTC)		✓	✓	✓	✓	✓		✓		✓	✓	✓	✓	Yes
Karmarkar *et al.*, 2021	Long-term care	✓		✓	✓	✓				✓		✓			Yes
Lane, 2018; Worth 2020	Hospital	✓	✓	✓	✓	✓	✓				✓	✓			Yes
Lesho *et al.*, 2018	Hospital	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓	No
McGann *et al.*, 2023	Hospital		✓	✓	✓	✓	✓	✓	✓		✓		✓		No
O'Connor *et al.*, 2019	Multiple (e.g., hospital + LTC)					✓	✓					✓			Yes
Ohashi *et al.*, 2023	Hospital		✓	✓	✓							✓			No
Osbourne Townsend *et al.*, 2021	Hospital	✓	✓	✓	✓	✓		✓							No
Pacilli *et al.*, 2020	Long-term care			✓		✓	✓			✓	✓	✓	✓	✓	Yes
Patterson *et al.*, 2020	Hospital	✓				✓	✓	✓		✓	✓				Yes
Prestel *et al.*, 2021	Hospital			✓		✓		✓		✓		✓			Yes
Proctor *et al.*, 2021	Long-term care					✓								✓	No
Reimer-McAtee *et al.*, 2021	Multiple (e.g., hospital + LTC)	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓			No
Rowlands *et al.*, 2023	Multiple (e.g., hospital + LTC)	✓	✓	✓	✓						✓				No
Sexton *et al.*, 2021	Hospital			✓	✓						✓				No
Schelenz *et al.*, 2016	Hospital		✓	✓	✓	✓	✓	✓	✓		✓			✓	Yes
Schwartz *et al.*, 2017	Hospital		✓	✓	✓	✓	✓	✓	✓		✓				No
Steinmann *et al.*, 2021	Hospital		✓	✓	✓	✓					✓				No
Sticchi *et al.*, 2023	Hospital		✓	✓	✓	✓	✓			✓	✓	✓	✓		Yes
Taori *et al.*, 2019	Hospital		✓	✓	✓	✓	✓			✓	✓		✓	✓	Yes
Vu *et al.*, 2022	Hospital	✓		✓	✓	✓					✓				Yes
Walits *et al.*, 2020	Hospital		✓	✓	✓			✓		✓			✓		No
Waters *et al.*, 2023	Long-term care	✓				✓				✓		✓			Yes
Totals		12	17	26	24	26	17	11	3	12	21	14	10	8	Yes = 19 No = 12

Eyre *et al.*, 2018; Hinrichs *et al.*, 2022; Karmarkar *et al.*, 2021; Lane *et al.*, 2019; Lesho *et al.*, 2018; Reimer-McAtee *et al.*, 2021; Worth *et al.*, 2020), notifying public health authorities (Austin *et al.*, 2022; Karmarkar *et al.*, 2021; Lane *et al.*, 2019; Reimer-McAtee *et al.*, 2021; Waters *et al.*, 2023; Worth *et al.*, 2020), communications with transfer facilities (Austin *et al.*, 2022; Karmarkar *et al.*, 2021; O'Connor *et al.*, 2019; Prestel *et al.*, 2021; Sticchi *et al.*, 2023), and engagement and communication with partners/colleagues at a local, national and international level (Austin *et al.*, 2022; Eckbo *et al.*, 2021; Reimer-McAtee *et al.*, 2021; Waters *et al.*, 2023). Austin *et al.* (2022) used a combination of these strategies, included hosting a conference call with partners to alert them to the transmission event and the facility's plan.

Contact tracing

A majority of reports (n=26) recorded the use of contact tracing. Procedures for this practice were variable in terms of who was screened, frequency of screening and clearance criteria. Most reports indicated screening of patients only on the same ward or unit during contact tracing (Alanio *et al.*, 2022; Brooks *et al.*, 2019; Eckbo *et al.*, 2021; Eyre *et al.*, 2018; Lane *et al.*, 2018; Lesho *et al.*, 2017; McGann *et al.*, 2023; Osbourne Townsend *et al.*, 2021; Patterson *et al.*, 2020; Prestel *et al.*, 2021; Reimer-McAtee *et al.*, 2021; Sticchi *et al.*, 2023; Waters *et al.*, 2023; Worth *et al.*, 2020), whereas others screened patient contacts who had epidemiologic links to index patients (Adams *et al.*, 2018; Austin *et al.*, 2022; Corcione *et al.*, 2022; O'Connor *et al.*, 2019; Schelenz *et al.*, 2016; Taori *et al.*, 2019)(n=6). For example, Corcione *et al.* (2022) conducted screening for all close patient contacts, including patients who shared the same room with the index case, those who were cared for by the same healthcare staff and those who occupied the same bed of the index case after cleaning and disinfection. Weekly contact screening was the most common timeline for contact tracing (Alanio *et al.*, 2022; Corcione *et al.*, 2022; Eckbo *et al.*, 2021; Eyre *et al.*, 2018; Lesho *et al.*, 2017; Osbourne Townsend *et al.*, 2021; Patterson *et al.*, 2020; Sticchi *et al.*, 2023; Taori *et al.*, 2019), followed by bi-weekly screening (Austin *et al.*, 2022; Karmarkar *et al.*, 2021; Waters *et al.*, 2023).

C. auris negative screening swabs over three consecutive weeks was the accepted clearance criteria for contacts in six studies (Alanio *et al.*, 2022; Eckbo *et al.*, 2021; Eyre *et al.*, 2018; Osbourne Townsend *et al.*, 2021; Schelenz *et al.*, 2016; Taori *et al.*, 2019). This was established in a report published by Eyre *et al.* (2018), where they estimated the sensitivity of a single *C. auris* screen to be 78% and defined loss of colonization to be three consecutive negative screens.

Environmental cleaning and disinfection

C. auris outbreak assessments at multiple LTC facilities observed the use of inappropriate cleaning products (i.e., household cleaners), inadequate disinfectant concentrations, and uncertainty regarding cleaning frequency and surfaces cleaned by staff (Adams *et al.*, 2018; Karmarkar *et al.*, 2021).

Reports describing enhanced cleaning and disinfection of surfaces in the environment of a patient known to be *C. auris* positive mentioned the use of chlorine-based disinfectants (1:10 bleach/sodium hypochlorite solution or 1000pm chlorine-based solution), hydrogen peroxide, peracetic acid or sporicidal disinfectants. Details on enhanced cleaning frequency ranged from daily to up to four times a day and in case of spills or visible dirt (Alanio *et al.*, 2022; Corcione *et al.*, 2022; Eckbo *et al.*, 2021; Lane *et al.*, 2018; Lesho *et al.*, 2018; Worth *et al.*, 2020; O'Connor *et al.*, 2018; Reimer-McAtee *et al.*, 2021; Schelenz *et al.*, 2016; Taori *et al.*, 2019). Six reports stated cleaning frequency of high-touch surfaces was increased to more than two times a day (Alanio *et al.*, 2022; Corcione *et al.*, 2022; Eckbo *et al.*, 2021; Reimer-McAtee *et al.*, 2021; Schelenz *et al.*, 2016; Taori *et al.*, 2019). The addition of no-touch disinfection technologies, such as hydrogen peroxide vapor or ultraviolet-C light, in terminal cleaning practice was noted in 11 studies (Austin *et al.*, 2022; Corcione *et al.*, 2022; de St. Maurice *et al.*,2023; Lesho *et al.*, 2018; McGann *et al.*, 2023; Osbourne Townsend *et al.*, 2022; Patterson *et al.*, 2020; Prestel *et al.*, 2021; Reimer-McAtee *et al.*, 2021; Schelenz *et al.*, 2016; Taori *et al.*, 2019). Some cleaning processes were validated by supervisor or charge nurse inspections, cleaning checklists, adenosine triphosphate validation, and the testing of environmental surface swabs for *C. auris* (de St. Maurice *et al.*,2023; Karmarkar *et al.*, 2021; Osbourne Townsend *et al.*, 2022; Pacilli *et al.*, 2020; Patterson *et al.*, 2020; Taori *et al.*, 2019). Furthermore, enhanced cleaning practices in some instances were coupled with extensive decluttering of the impacted wards/facilities (Eckbo *et al.*, 2021; Eyre *et al.*, 2018; Taori *et al.*, 2019).

Similar to environmental cleaning, cleaning and disinfection of medical equipment mentioned the use of agents with established effectiveness against *C. auris* such as those mentioned above. It is worth noting that several *C. auris* transmission events were linked to improperly cleaned or difficult to clean equipment in the patient care environment, such as axillary temperature probes and lanyards (Eyre *et al.*, 2018; Hinrichs *et al.*, 2022; Patterson *et al.*, 2020).

Fourteen reports mentioned environmental sample testing for *C. auris* contamination (Adams *et al.*, 2018; Alanio *et al.*, 2022; Corcione *et al.*, 2022; Eyre *et al.*, 2018; Hinrichs *et al.*, 2022; Lesho *et al.*, 2018; McGann *et al.*, 2023; O'Connor *et al.*, 2018; Osbourne Townsend *et al.*, 2022; Pacilli *et al.*, 2020; Patterson *et al.*, 2020; Reimer-McAtee *et al.*, 2021; Schelenz *et al.*, 2016; Sticchi *et al.*, 2023). These studies identified contamination on reusable and/or mobile devices/equipment (e.g., IV administration equipment, temperature probes, etc.), surfaces in *C. auris* positive patient rooms (e.g., recliner chair, bed rails, etc.), and to a minimal extent surfaces outside patient rooms (e.g., keypad and hand washing sink) (Adams *et al.*, 2018; Alanio *et al.*, 2022; Eyre *et al.*, 2018; Lesho *et al.*, 2018; Pacilli *et al.*, 2020; Patterson *et al.*, 2020; Schelenz *et al.*, 2016; Taori *et al.*, 2019; Waters *et al.*, 2023). Most tested surfaces were *C. auris* negative after specified cleaning and disinfection regimens, but a small number of samples) from three studies, ranging from two to three surfaces per study, remained *C. auris* positive post-cleaning and disinfection (Lesho *et al.*, 2018; Patterson *et al.*, 2020; Waters *et al.*, 2023).

Laboratory identification

For the majority of studies (n=17) reporting their isolate identification methods, the use of Matrix-assisted Laser Desorption/Ionization Time-of-flight (MALDI-TOF) in the initial speciation of their isolates was identified (Adams *et al.*, 2018; Alanio *et al.*, 2022; de St Maurice *et al.*, 2023; Eckbo *et al.*, 2021; Lane *et al.*, 2018; Worth *et al.*, 2020; Lesho *et al.*, 2018; Pacilli *et al.*, 2020; Patterson *et al.*, 2020; Prestel *et al.*, 2021; Reimer-McAtee *et al.*, 2021; Rowlands *et al.*, 2023; Steinmann *et al.*, 2021; Sticchi *et al.*, 2023; Taori *et al.*, 2019; Vu *et al.*, 2022; Sexton *et al.*, 2021). Two studies utilized whole-genome sequencing (Eyre *et al.*, 2018; Lane *et al.*, 2018) to identify isolates, and two sent isolates to a reference lab for identification, where specific methods were not reported (Sticchi *et al.*, 2023; Rowlands *et al.*, 2023). No issues with isolate identification (e.g., inaccurate speciation) using reported methods were identified. Confirmation of isolate speciation was also reported, in particular, sequencing of internal transcribed spacer regions half and D1D2 28s rDNA. The use of regional reference laboratories to confirm identification of isolates was also reported. These confirmations were frequently reported as being completed to ensure accurate species identification by the MALDI-TOF system.

Personal protective equipment

Twenty-six studies reported the use of PPE when caring for patients. Of the studies reporting details of type of PPE used (n=3), included gown and gloves (Hinrichs *et al.*, 2022; Walits *et al.*, 2020) and gown and gloves with an apron (Schelenz *et al.*, 2016). No specific details were given on other PPE parameters such as gown fluid resistance or whether PPE should be worn at all times while in the patient care area.

Other interventions

Other reported *C. auris* IPC measures not captured within the above categories included chlorhexidine gluconate (CHG) bathing (Corcione *et al.*, 2022; Eckbo *et al.*, 2021; Hinrichs *et al.*, 2022; Pacilli *et al.*, 2020; Proctor *et al.*, 2021; Schelenz *et al.*, 2016; Taori *et al.*, 2019), the use of ABHS hallway dispensers (Pacilli *et al.*, 2020), increased presence of IPC professionals (Hinrichs *et al.* 2022), and increased frequency of changing and laundering of linens and gowns of cases and contacts (Eckbo *et al.*, 2021). Although the effectiveness of CHG bathing in the reduction of *C. auris* skin bioburden is uncertain, several studies used this practice with patients who are *C. auris* positive (Corcione *et al.*, 2022; Eckbo *et al.*, 2021; Hinrichs *et al.*, 2022; Pacilli *et al.*, 2020; Proctor *et al.*, 2021; Schelenz *et al.*, 2016; Taori *et al.*, 2019).

DISCUSSION

This review identified 32 reports detailing *C. auris* IPC interventions in hospital and LTC facilities with evidence applicable to Canadian settings. Reports with no onward transmission beyond the index case more often included the use of risk-factor-based screening, private accommodation with dedicated toileting facilities, the use of PPE and contact precautions and the application of no-touch cleaners and disinfectants. This suggests these *C. auris* IPC interventions may be effective at halting transmission of *C. auris* in healthcare settings, findings that are consistent with reviews conducted by others (Ahmad *et al.*, 2021; Paudel, 2023; Sanyaolu *et al.*, 2022; Asadzadeh *et al.*, 2023).

The overall identified body of evidence was predominantly appraised to be of medium to high quality, providing some confidence regarding the incorporation of applicable findings into *C. auris* IPC guidance. However, as *C. auris* is an emerging pathogen, there is a general paucity of data regarding its environmental reservoirs, transmission dynamics and prevention. For instance, information regarding the role of linen management in *C. auris* IPC was limited. The role of linens and other surfaces in the transmission of *C. auris* should be better investigated, as recent evidence indicates that *C. auris* can survive in both planktonic and biofilm forms on various surfaces for up to three weeks (Dire *et al.*, 2023), and has been found on surfaces such as identification lanyards during outbreaks (Patterson *et al.*, 2021). Additional research regarding duration of precautions, risk factors for colonization/infection, and effectiveness of no-touch disinfection technologies for *C. auris* (e.g., UV) would fill vital gaps in current knowledge.

Although a number of relevant reports were identified, none directly measured the effectiveness of individual interventions on transmission. Most reported on a bundle of *C. auris* IPC interventions implemented following the identification of *C. auris* positive individual(s), and prevalence rates pre- and post-intervention were not reported. As such, it was difficult to ascertain the effectiveness of individual *C. auris* IPC measures. Muti-centre comparisons of varying outbreak interventions or investigations pre- and post-*C. auris* IPC would help to better determine the effectiveness of each intervention. Despite this knowledge gap, measures reported in this review were generally consistent with existing guidance recommendations.

A key strength of this review is that the search was limited to healthcare settings in G12 countries and New Zealand, to ensure compatibility of findings. However, due to variation in health standards and IPC practices, findings of these studies may not be generalizable to countries that are not part of the G12 and New Zealand. Further strengths of this review include the utilization of standardized evidence screening, extraction and appraisal processes, and the inclusion only of studies appraised as being of medium-to-high quality. Finally, to our knowledge, at the time of authorship, this was the first Canadian systematic review encompassing 986 articles on the management of *C. auris*, adding to the overall body of evidence regarding *C. auris* IPC.

This study was limited by the lack of statistical result pooling as there was a high degree of heterogeneity across settings and reporting of *C. auris* IPC. Furthermore, the possibility of reporting bias should also be considered, as only *C. auris* IPC interventions that were explicitly reported were captured and authors may be more likely to report successful *C. auris* IPC interventions and outcomes in comparison to less successful experiences. It is also possible that more specific details were left out to accommodate brevity in reporting of their experiences and do not truly represent the entire suite of interventions used. Additionally, while all instances of nosocomial transmission were explicitly reported by the authors, in reports identified as no transmission, there were several instances where reporting of lack of transmission was inferred based on report details, instead of being explicitly stated by the authors (e.g., it was reported that patients were placed on precautions on arrival due to other reasons and no transmission was reported by the authors), which should be taken into consideration when interpreting the results (Rowlands *et al.*, 2023, Sexton *et al.*, 2021, Schwartz *et al.*, 2017).

In closing, this review identified numerous healthcare institutions reporting a lack of adequate screening as being an important factor in the introduction of *C. auris* to healthcare settings. In Canada, *C. auris* is currently only reportable in Alberta and British Columbia, and as such greater jurisdictional reporting of cases to public health authorities would be helpful in understanding the true *C. auris* burden in Canadian healthcare settings. Healthcare institutions would also benefit from timely identification and reporting of new cases, more robust risk-based patient screening programs, an overall awareness and suspicion of the possibility of *C. auris* colonization or infection during patient encounters and ensuring the application of fulsome *C. auris* IPC during patient care. Improved control of the spread of *C. auris*, and AROs in general, would help to reduce morbidity and mortality associated with healthcare-acquired infections, reduce spread to community settings, and help to improve anti-microbial stewardship.

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