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# Educational intervention to improve infection prevention and control practices in four companion animal clinics in Switzerland

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SUMMARY

***Background:*** Infection prevention and control (IPC) practices vary among companion animal clinics, and outbreaks with carbapenemase-producing Enterobacterales (CPE) have been described.

***Aim:*** To investigate the effect of an IPC intervention (introduction of IPC protocols, IPC lectures, hand hygiene campaign) in four companion animal clinics.

***Methods:*** IPC practices, environmental and hand contamination with antimicrobial-resistant micro-organisms (ARM) and hand hygiene (HH) were assessed at baseline, and 1 and 5 months after the intervention.

***Results:*** Median IPC scores (% maximum score) improved from 57.8% (range 48.0–59.8%) to 82.9% (range 81.4–86.3%) at 1-month follow-up. Median cleaning frequency assessed by fluorescent tagging increased from 16.7% (range 8.9–18.9%) to 30.6% (range 27.8–52.2%) at 1-month follow-up and 32.8% (range 32.2–33.3%) at 5-month follow-up. ARM contamination was low in three clinics at baseline and undetectable after the intervention. One clinic showed extensive contamination with ARM including CPE before and after the intervention (7.5–16.0% ARM-positive samples and 5.0–11.5% CPE-positive samples). Mean HH compliance improved from 20.9% [95% confidence interval (CI) 19.2–22.8%] to 42.5% (95% CI 40.4–44.7%) at 1-month follow-up and 38.7% (95% CI 35.7–41.7%) at 5-month follow-up. Compliance was lowest in the pre-operative preparation area at baseline (11.8%, 95% CI 9.3–14.8%) and in the intensive care unit after the intervention (28.8%, 95% CI 23.3–35.1%). HH compliance was similar in veterinarians (21.5%, 95% CI 19.0–24.3%) and nurses (20.2%, 95% CI 17.9–22.7%) at baseline, but was higher in veterinarians (46.0%, 95% CI 42.9–49.1%) than nurses (39.0%, 95% CI 36.0–42.1%) at 1-month follow-up.

***Conclusion:*** The IPC intervention improved IPC scores, cleaning frequency and HH compliance in all clinics. Adapted approaches may be needed in outbreak situations.



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## Introduction

The emergence of antimicrobial-resistant micro-organisms (ARM) is a major public health threat. Healthcare institutions play an important role in the transmission of ARM [1—6]. Over the past few years, the spread of highly critical drug-resistant organisms such as carbapenemase-producing Enterobacterales (CPE), endemic to countries such as Greece, Malta, Italy and Turkey, has challenged healthcare settings worldwide [7]. Since 2010, CPE have been described in human healthcare settings in Switzerland [8]. Recently, several outbreaks comprising meticillin-resistant staphylococci (MRS), extended-spectrum beta-lactamase-producing Enterobacterales (ESBL-E) and CPE have been documented in companion animal clinics, also in Switzerland [2,5,6,9,10]. Besides ARM, companion animal clinics face numerous highly contagious and zoonotic diseases [11], and transmission chains within these clinics can affect human and animal health [12—15]. Intensive medical care in small animal clinics may foster the development and spread of ARM. Animal patients receive invasive procedures similar to those in human hospitals, and are treated with a variety of antimicrobials. Additionally, owners and their pets live in close contact within households, which promotes the transmission of pathogens, including ARM [16,17].

Infection prevention and control (IPC) guidelines are key elements in human health care to prevent the development and spread of ARM and other pathogens [18]. The cornerstones of IPC guidelines are hand hygiene, staff education, personal protective equipment, adequate cleaning and disinfection, prudent use of antimicrobials and isolation measures [19—21]. Improvements in IPC practices result in better safety for patients and staff, reduced hospitalization costs, and increased patient and staff satisfaction. The World Health Organization (WHO) established guidelines on core components of infection prevention and control programmes to be implemented at national and acute human healthcare facility level [20]. Veterinary clinics and practices differ from human healthcare settings in relation to infrastructure, available resources, patient care and handling. Therefore, IPC guidelines for veterinary institutions need to be adapted and applicable to private clinics and practices. Guidelines on IPC in companion animal medicine have been published, but as there is currently no legislation which regulates IPC practices in companion animal clinics and practices in Switzerland and other European countries, IPC implementation is optional and data on IPC in these settings are sparse. A previous study showed that IPC practices vary considerably across companion animal clinics and practices in Switzerland [19]. As a consequence, clinics with low IPC scores as evaluated by direct audits showed extensive environmental contamination with ARM, resulting in transmission opportunities to patients and staff. Hence, considerable colonization of patients with ARM during hospitalization was documented in extensively contaminated clinics [2,19,22]. These isolates included ARM of public health concern, such as MRS, ESBL-E and CPE [2,19,22]. Closely related ARM in patients, personnel and the clinic environment were documented, which underlines the need to break transmission chains by fostering IPC in these settings [2,23]. In addition to swab sampling, surface disinfection can also be evaluated with fluorescent tagging [24]. Both methods have shown that there is a need to improve cleaning and disinfection in companion animal clinics as many high-touch surfaces are not cleaned in a frequent and adequate manner [16,24].

Hand hygiene is regarded as a key element of IPC because stringent hand hygiene of healthcare workers is one of the most effective measures to interrupt transmission chains in healthcare settings [25]. Results from the few available studies on hand hygiene in companion animal veterinary institutions in the USA, Australia and Canada showed that compliance with hand hygiene guidelines was poor (14—27%), but could be increased up to 46% with hand hygiene campaigns [26—29]. Only one published abstract reported on the sustainability of the improvements, and found that although hand hygiene compliance dropped again after 6 months, it remained above baseline [29]. The studies used different techniques to define and evaluate hand hygiene; as such, it is difficult to compare the results. Other studies looked at hand contamination of veterinary staff and documented a variety of ARM on the hands of veterinary healthcare workers [10,30,31].

The first hand hygiene guidelines were introduced in human health care in the 1980s [32,33]. WHO offers a comprehensive multi-modal hand hygiene campaign for healthcare settings, and the WHO guidelines on hand hygiene in health care are well established in human hospitals [34]. The guidelines differentiate the patient zone (the patient and immediate surroundings, Figure 1) from the healthcare area (all surfaces in the healthcare setting outside the patient zone). Within the patient zone, critical sites are defined, such as body sites or medical devices that must be protected against micro-organisms. The WHO guidelines define five moments for hand hygiene, which represent hand hygiene indications for healthcare workers with the goal of preventing the introduction of micro-organisms via the hands of healthcare workers into the patient zone, between critical sites within the patient zone, and the spread of micro-organisms from the patient zone to the healthcare area. According to these guidelines, hand

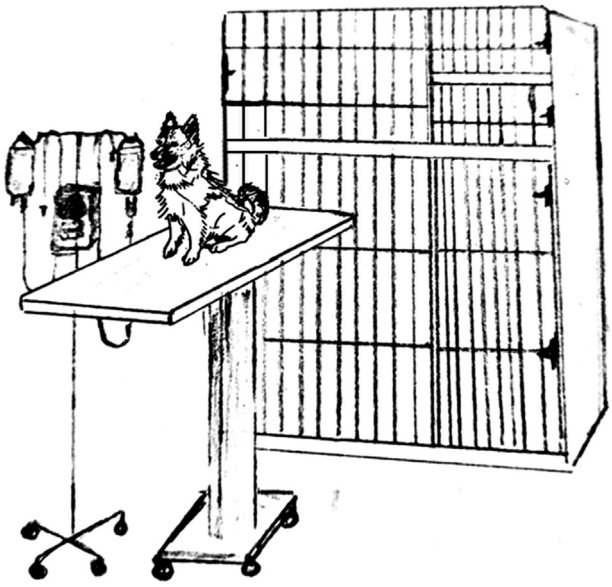

**Figure 1.** The patient and the patient zone comprising all areas that could potentially come into contact with the patient, such as the table, the ward, the infusion pump and intravenous lines.

hygiene should be applied: (i) before patient contact; (ii) after body fluid exposure risk; (iii) after touching the patient's surroundings; (iv) before clean/aseptic procedures; and (v) after patient contact. Both hand disinfection (i.e. use of alcohol-based hand sanitizer) and handwashing with water and soap are considered hand hygiene procedures [35]. Teaching and promoting these guidelines to healthcare workers can improve hand hygiene compliance considerably in human hospitals, and has been reported to decrease the rate of nosocomial infections by almost 50% [34,36]. The WHO guidelines were recently applied to investigate hand hygiene compliance in companion animal clinics and practices in Switzerland, and hand hygiene compliance of the veterinary staff ranged from 26% to 47%. Hand hygiene compliance was lowest before clean/aseptic procedures, and highest after body fluid exposure risk [31,37].

To the authors' knowledge, no study to date has assessed whether a multi-modal IPC intervention can improve IPC practices and hand hygiene compliance, and reduce environmental contamination with ARM in companion animal clinics. As such, this study assessed baseline IPC practices; hand hygiene compliance; hand contamination of veterinary staff; cleaning frequency; and environmental contamination with CPE, ESBL-E, MRS and vancomycin-resistant enterococci (VRE) in four companion animal clinics in Switzerland. Each clinic was part of a multi-modal IPC intervention that comprised: (i) recruitment of an infection control preventionist; (ii) implementation of written IPC guidelines; (iii) introduction of written cleaning/disinfection and isolation protocols throughout the clinic; and (iv) a comprehensive hand hygiene campaign that included a lecture, hand hygiene posters, practical hand hygiene trainings and observation–feedback sessions. After the intervention, the above-mentioned evaluations were repeated 1 (four clinics) and 5 months later (two clinics) and the results were compared with baseline values.

## Methods

### *Study set-up*

Four private companion animal clinics (Clinics 1–4) located in three different geographic regions of Switzerland (east, west and central) were recruited by direct contact. Participation was voluntary and was not reimbursed. Both clinics with and without pre-existing IPC guidelines were included. The study focused on companion animal clinics (>20 staff members, 24-h emergency service, and receiving first opinion and referred cases) in Switzerland. This decision was based on results of a previous study in companion animal clinics and practices in Switzerland which indicated that despite low IPC scores in first opinion practices (as assessed by direct audit), environmental contamination with ARM in first opinion practices was low [19]. The companion animal clinics were offered IPC evaluation by direct audits, evaluation of hand hygiene compliance and hand contamination with ARM, evaluation of environmental contamination with ARM and assessment of cleaning frequency by fluorescent tagging both before and after the IPC intervention, and support in the development of IPC guidelines and written protocols and cleaning/disinfection and isolation measures, all free of charge.

The study set-up and the timeline are shown in Figure S1 (see online supplementary material). Due to a study interruption caused by the coronavirus disease 2019 (COVID-19) pandemic, the baseline microbiological evaluations took place between November 2019 and March 2020 (Clinics 1, 3 and 4) and again in September 2020 (Clinic 2). IPC audits were performed in the same period in each clinic, but results were rechecked between July 2021 and August 2021 (before development of the IPC intervention) and scores were adapted if necessary. Baseline hand hygiene evaluations and fluorescent tagging were performed from July 2021 to August 2021 after COVID-19 restrictions had been lifted in Switzerland. Thereafter, the clinic-specific IPC interventions were developed (August 2021–January 2022) with the selected infection control preventionist for each clinic. The multi-modal IPC interventions were introduced to the staff, and lectures and hand hygiene trainings were held between January 2022 and April 2022; the IPC intervention lasted for 1 week per clinic. Clinics 1–4 were re-evaluated 1 month after the intervention (April 2022–July 2022) using the same methodology as for establishment of the baseline data. In Clinics 1 and 2 (the best and the worst performing at 1-month follow-up, respectively), a second re-evaluation took place at 5 months after the intervention (June 2022 and September 2022, respectively) to assess the long-term effect of the intervention. The 5-month follow-up comprised evaluation of hand hygiene compliance, cleaning frequency and environmental contamination with ARM. Follow-up data for each clinic were compared with baseline data. Selected results from the baseline evaluation of Clinic 2 have been published elsewhere [10].

### *IPC evaluation by direct audit*

IPC practices in Clinics 1–4 were evaluated by a 1-day direct audit by two of the authors (KD, BW), and an adapted IPC audit protocol comprising 15 areas of IPC was applied [10,21]. The IPC audit protocol was originally published as part of the infection control, prevention and biosecurity guidelines of the American Animal Hospital Association (AAHA). The audit assessed general IPC management, staff education, cleaning/disinfection, management of waste, vector control, equipment in examination rooms, isolation measures, handling of patients with ARM, hand hygiene equipment, personnel hygiene, protection of employees, protective clothing, medication, use of antimicrobials and miscellaneous. A template for the audit has been published previously [10]. A scoring system (0, not fulfilled; 1, partially fulfilled; 2, completely fulfilled) was applied as described previously [19], and the percentage of the total score ($N$=102) was calculated. After baseline evaluation, the participating clinics received a written report of the audits, highlighting the IPC deficits and an action plan for the IPC intervention.

### *Hand hygiene compliance*

Hand hygiene compliance was assessed by direct observation using the CleanHands application (Swissnoso, National Centre for Infection Prevention, Bern, Switzerland) as described elsewhere [31,37]. All hand hygiene observations were performed in-person by the same observer (KD). Based on previously obtained data [31,37], hand hygiene compliance of 32% at baseline was assumed, and a sample size of 500 hand hygiene events per clinic (100 observations per study area) was used to allow differentiation of a 10% difference in hand

hygiene compliance before and after the intervention [38]. All hand hygiene observations were carried out by the same observer (KD), who has evaluated hand hygiene for other studies previously, and received prior training by an experienced human infection control practitioner at the University Hospital in Zurich, Switzerland [10,31]. Hand hygiene was evaluated as published elsewhere [31,37,38], based on the WHO's five moments for hand hygiene, described in detail in the WHO guidelines on hand hygiene in health care [34]. The five moments comprise 'before touching a patient', 'before clean/aseptic procedure', 'after body fluid exposure risk', 'after touching a patient' and 'after touching patient surroundings'. In accordance with the WHO guidelines, both hand disinfection with alcohol-based hand rubs and handwashing with water and soap, but not the use of gloves, were considered successful hand hygiene procedures [38]. The hand hygiene observations were conducted in five different areas of the clinics: the pre-operative preparation area; the intensive care unit (ICU); the wards; the consultation area; and the examination area. If a certain area was not present in a clinic, the 500 observations were spread evenly across the existing areas. Additionally, three professional groups (veterinarians, nurses, others) were assessed. After recording, data were extracted from the software as Excel files (Microsoft Corp., Redmond, WA, USA) for statistical analyses. Non-coded hand hygiene observations (i.e. those that could not be matched to one of the five moments for hand hygiene) were excluded from analysis. Hand hygiene compliance (% of successful hand hygiene procedures per total number of observed hand hygiene observations) with 95% binomial confidence intervals (CI) were calculated using the hybrid Wilson/Brown method with GraphPad Prism Version 9.5.1 (GraphPad Software, San Diego, CA, USA), and hand hygiene compliance was compared before and after the intervention.

### *Environmental contamination with ARM*

To assess environmental contamination with ARM in Clinics 1—4, 200 pre-defined high-touch surfaces per clinic were sampled from all clinical areas using pre-moistened cotton swabs, as described previously [10,16]. A list of high-touch surfaces has been published previously [10]. In each clinic, the sampling was performed during the first half of the day on four different sampling days over a 2-week period (50 samples per day) to account for daily variation in environmental contamination [16]. At 5-month follow-up in Clinics 1 and 2, 100 pre-defined high-touch surfaces per clinic were sampled on two sampling days (50 samples per day). The specific surfaces to be tested were not disclosed prior to sampling, and the participating clinics were instructed to refrain from performing any special cleaning procedures prior to environmental swabbing. Samples were screened for the presence of CPE, ESBL-E, MRS and VRE (for details see below). The percentage of positive surfaces (before and after intervention) with 95% CI was calculated using GraphPad Prism Version 9.5.1.

### *Cleaning frequency*

Fluorescent markers (DAZO Fluorescent Marking Gel, ECOLAB, Monheim, Germany) were used as a non-culture method to evaluate cleaning frequency in the clinics according to published methods [24]. A total of 90 surfaces from a list of 30 surfaces (Table S1, see online supplementary material; each surface was sampled three times) were marked and re-evaluated for fluorescence after 24 h. The sampled surfaces were not disclosed to the staff. Fluorescent tags and environmental sampling were conducted on the same day but independently of each other, and thus did not impact one another. The percentage of successfully cleaned surfaces with 95% CI was calculated and compared before and after the intervention using GraphPad Prism Version 9.5.1.

### *Hand contamination with ARM*

In total, 20 hand swabs per clinic were collected from the veterinary staff at baseline sampling and at 1-month follow-up using previously described methods [10,31]. Briefly, hand swabs of the entire palm, fingers and thumb of the dominant hand were collected from 20 veterinary staff members without announcement, and immediately before and after patient contact using a sterile cotton swab moisturized with 0.85% saline solution. If gloves were worn, hand swabs were taken from the gloved hand. All swabs were analysed for the presence of ESBL-E, CPE, MRS and VRE. Participation of the employees was voluntary, and written informed consent was obtained. The percentage of positive hand swabs with 95% CI was calculated and compared before and after the intervention using GraphPad Prism Version 9.5.1. The study protocol was approved by the Swiss Ethics Committees on research involving humans (Approval No 2019-00768).

### *Microbiological evaluation*

Microbiological analysis of the samples was carried out in accordance with standard protocols, as described previously [10,31]. Swabs were processed within 12 h of sample collection.

The homogenate of all samples was enriched (37 °C, 24 h), followed by selective enrichment for ESBL-E and CPE in Enterobacterales enrichment broth (Oxoid, Basingstoke, UK), brain heart infusion (BioRad, Hercules, CA, USA) with 6.5% saline for VRE, and Mueller-Hinton broth (Oxoid) with 6.5% saline, followed by an enrichment in tryptone soy broth (Becton Dickinson, Allschwil, Switzerland) with 4 mg/L cefoxitin and 75 mg/L aztreonam for the detection of MRS. ESBL-E were screened using the chromogenic medium Brilliance ESBL Agar (Oxoid), CPE were screened using chromID CARBA SMART Bi-Plate-Agar (bioMérieux, Marcy-l'Étoile, France), VRE were screened using Brilliance VRE Agar (Oxoid), and MRS were screened using Brilliance MRSA2 Agar (Oxoid), in accordance with the manufacturer's instructions. Species identification was conducted using matrix-assisted laser desorption/ionization time-of-flight mass spectrometry (Bruker Daltronics, Bremen, Germany).

Polymerase chain reaction (PCR) was carried out to screen for the presence of genes encoding $bla_{\text{CTX-M}}$ group enzymes, $bla_{\text{SHV}}$ and $bla_{\text{TEM}}$, as described previously [39—42]. PCR targeting $bla_{\text{VIM}}$, $bla_{\text{KPC}}$, $bla_{\text{OXA-48}}$-like and $bla_{\text{NDM}}$ genes was carried out using custom synthesized primers (Microsynth, Balgach, Switzerland) and conditions published previously [43,44]. PCR for the presence of *mecA* and *mecC* was conducted using custom synthesized primers (Microsynth), as described previously [45,46].

Antimicrobial susceptibility testing was carried out for all ESBL-E and CPE isolates as described previously [16].

Antimicrobial susceptibility testing was performed for Enterobacterales in accordance with the Clinical and Laboratory Institute (CLSI) performance standards [47] using the disc diffusion method on Mueller-Hinton plates (Oxoid) and the 16 antibiotics: ampicillin, amoxicillin with clavulanic acid, azithromycin, cefazolin, cefepime, cefotaxime, chloramphenicol, ciprofloxacin, fosfomycin, gentamicin, kanamycin, nalidixic acid, nitrofurantoin, streptomycin, sulfamethoxazole trimethoprim, and tetracycline (Becton Dickinson, Allschwil, Switzerland). Results were interpreted according to CLSI standards [47]. For azithromycin, an inhibition zone of $\leq$12 mm was interpreted as resistant. In addition, the minimal inhibitory concentrations of the carbapenem antibiotics ertapenem, imipenem and meropenem were determined for all CPE isolates.

For MRS isolates, antimicrobial susceptibility profiling was performed using the automated VITEK two compact system (bioMérieux) with the AST-GP80 susceptibility testing card (bioMérieux, Nürtingen, Germany).

### *Intervention*

An infection control preventionist (veterinarian or veterinary nurse) was elected from the existing staff and established in each clinic; this individual was responsible for IPC implementation and future IPC maintenance. If possible, a person with a background in IPC was chosen. If such a person was not present, a veterinarian or veterinary nurse with an interest in IPC was selected. Comprehensive IPC guidelines written by the study personnel and based on published protocols [48,49] were introduced in each clinic. If IPC guidelines were already in place, these were used as a basis and adapted. The focus of the intervention period was on adequate and written cleaning and disinfection protocols, personnel hygiene (i.e. working clothes and shoes, no jewellery, no long or artificial fingernails, no food consumption in patient areas, no storage of staff food in refrigerators in patient areas, laundry guidelines), hand hygiene and hand hygiene equipment, isolation measures, information dissemination among employees and involvement of employees in IPC. The guidelines were adapted to fit the specific needs and address as many IPC deficits identified during the baseline evaluation as possible. If implementation of certain aspects was considered unfeasible, the guideline was adapted. The final IPC guidelines were approved by the clinic directors. Written cleaning and disinfection and isolation protocols were established for each clinic and put up throughout the clinic. IPC development and implementation in Clinics 1—4 was guided and supported by the study authors by regular meetings with the infection control preventionists between August 2021 and January 2022. The IPC interventions took place between January 2022 and April 2022 (1 week per clinic). The interventions included a half-day lecture by the first author to introduce the IPC guidelines and cleaning/disinfection and isolation protocols to all staff members. The lecture focused on the following topics: introduction on the importance of IPC in veterinary clinics; WHO guidelines on hand hygiene (i.e. handwashing vs hand disinfection, correct use of gloves, hand hygiene in the clinical setting: five moments for hand hygiene), personnel hygiene, newly implemented cleaning and disinfection protocols, and isolation measures specific to each clinic.

The hand hygiene intervention comprised a hand hygiene campaign, including a lecture (see above), a poster, a practical hand hygiene training session and an observation—feedback session [50]. Practical hand hygiene training performed with the staff used fluorescent hand disinfectant to train hand disinfection techniques. Observation—feedback sessions were carried out as published previously [50].

### *Staff feedback on IPC intervention*

Barriers and facilitators for the IPC intervention were assessed qualitatively using a questionnaire (Table S2, see online supplementary material) sent by e-mail to all staff members of the clinics (around 20—80 staff/clinic) after the IPC intervention. The questionnaire addressed possible barriers and facilitators for implementation and execution of IPC, the quality of the given lectures, and an opportunity for the personnel to express constructive criticism. The personnel were asked to respond on a scale from 0 (very bad) to 10 (excellent).

## Results

### *Microbiological evaluation and cleaning frequency before and after the intervention*

Clinics 1—4 were based in three different parts of Switzerland. All clinics offered a 24-h emergency service. Clinics 1 and 2 had an ICU.

A summary of the IPC audit and microbiological results can be found in Table I. Baseline sampling detected selected ARM (ESBL-E, CPE and/or MRS) in all four clinics. Environmental contamination with ARM was negligible in Clinics 1, 3 and 4 (range of ARM-positive swabs: 0—1.5%), and was undetectable in the follow-up evaluations (Table I). Environmental contamination was extensive in Clinic 2 at baseline (15.5%), at 1-month follow-up (7.5%) and at 5-month follow-up (16.0%). Detailed microbiological results from the baseline evaluation in Clinic 2 have been published previously [10]. At 1 and 5-month follow-up, Clinic 2 showed contamination with OXA-48 CPE (7.5% and 5%, respectively) and ESBL-E (0.5% and 13%, respectively) in the environmental samples.

Hand contamination with ARM was low in all clinics during baseline sampling and ranged from 0% to 10%. Meticillin-resistant *Staphylococcus aureus* were the only ARM retrieved from the hands of healthcare workers. No ARM-positive hand swabs were detected after the intervention.

Fluorescent tagging revealed that a median of 16.7% (range 8.9—18.9%) of surfaces were cleaned in Clinics 1—4 within 24 h after fluorescent tagging (Table I). One and five months after the intervention, 30.6% (range 27.8—52.2%) and 32.8% (range 32.2—33.3%) of surfaces, respectively, were cleaned within 24 h.

### *IPC audit scores before and after the intervention*

The percentage of the total IPC audit score at baseline ranged from 48.0% (Clinic 1) to 59.8% (Clinic 4; Table I and Figure 1). The IPC audit scores of the clinics increased from a median value of 57.8% (range 48.0—59.8%) to 82.9% (range 81.4—86.3%) at 1-month follow-up. The IPC scores at 1 month were similar among the clinics (Table I). Detailed results of the IPC audits are shown in Table II. All clinics showed major

**Table I**
Overview of the results from the audit, hand hygiene evaluation, antimicrobial-resistant micro-organism (ARM) sampling and fluorescent tagging at baseline, 1-month follow-up and 5-month follow-up

| | Clinic 1 | | | Clinic 2 | | | Clinic 3 | | Clinic 4 | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Baseline | 1 month | 5 months | Baseline | 1 month | 5 months | Baseline | 1 month | Baseline | 1 month |
| Audit score in % of total score (102) | 48.0% | 86.3% | n.a. | 57.8% | 81.4% | n.a. | 57.8% | 82.4% | 59.8% | 83.3% |
| HH compliance (% [95% CI]) and number of observations | 30.3% [26.4–34.5] *N*=485 | 67.4% [63.2–71.4] *N*=500 | 52.5% [48.1–56.8] *N*=503 | 14.9% [12.1–18.2] *N*=525 | 30.5% [26.6–34.6] *N*=509 | 24.8% [21.2–28.8] *N*=500 | 21.1% [17.8–24.9] *N*=502 | 32.5% [28.5–36.7] *N*=493 | 18.2% [15.0–21.8] *N*=501 | 40.0% [35.8–44.3] *N*=508 |
| ARM-positive hand swabs (% [95% CI]) and number of samples | 0% *N*=20 | 0% *N*=20 | n.a. | 10%[a] [1.8–30.1] *N*=20 | 0% *N*=20 | n.a. | 10%[a] [1.8–30.1] *N*=20 | 0% *N*=20 | 0% *N*=20 | 0% *N*=20 |
| ARM-positive environmental swabs (% [95% CI]) and number of samples | 0.5% [0.0–2.8] *N*=200 | 0% *N*=200 | 0% *N*=100 | 15.5% [11.1–21.2] *N*=200 | 7.5% [4.6–12.0] *N*=200 | 16.0% [10.1–24.4] *N*=100 | 1.0% [0.2–3.6] *N*=200 | 0% *N*=200 | 1.5% [0.4–4.3] *N*=200 | 0% *N*=200 |
| Type of ARM in environmental swab | ESBL-E | | | CPE, ESBL-E, MRS | CPE, ESBL-E | CPE, ESBL-E, MRS | ESBL-E, MRS | | ESBL-E | |
| Fluorescent tags cleaned in % [95% CI] of total number of tags (90) | 8.9% [4.6–16.6] | 52.2% [39.9–60.1] | 33.3% [24.5–43.6] | 16.7% [10.4–25.7] | 30.0% [21.5–40.1] | 32.2% [23.5–42.4] | 18.9% [12.1–28.2] | 31.1% [22.5–41.3] | 16.7% [10.4–25.7] | 27.8% [19.6–37.8] |

HH, hand hygiene; CPE, carbapenemase-producing Enterobacterales; ESBL-E, extended-spectrum beta-lactamase-producing Enterobacterales; MRS, meticillin-resistant staphylococci; CI, confidence interval.

[a] Meticillin-resistant *Staphylococcus aureus* in all positive hand swabs.

**Table II**
Results from the audit conducted in the four participating clinics at baseline and 1-month follow-up

| | Clinic 1 | | Clinic 2 | | Clinic 3 | | Clinic 4 | |
|---|---|---|---|---|---|---|---|---|
| Audit area (total score) | Baseline | 1 month | Baseline | 1 month | Baseline | 1 month | Baseline | 1 month |
| IPC management (10) | 2 | 9 | 1 | 7 | 4 | 8 | 3 | 10 |
| Staff education (12) | 3 | 11 | 5 | 11 | 3 | 11 | 5 | 11 |
| Cleaning/disinfection (8) | 5 | 8 | 5 | 7 | 3 | 8 | 6 | 7 |
| Management of waste (4) | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 |
| Vector control (2) | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 |
| Equipment in examination rooms (4) | 3 | 3 | 2 | 2 | 3 | 3 | 3 | 3 |
| Isolation measures (6) | 3 | 6 | 3 | 6 | 5 | 6 | 4 | 6 |
| Patients with ARM (4) | 2 | 4 | 3 | 4 | 2 | 4 | 1 | 4 |
| Hand hygiene (8) | 5 | 7 | 4 | 4 | 6 | 6 | 3 | 4 |
| Personnel hygiene (12) | 6 | 10 | 10 | 10 | 8 | 8 | 10 | 10 |
| Protection of employees (8) | 2 | 4 | 5 | 7 | 2 | 4 | 2 | 4 |
| Protective clothing (6) | 3 | 6 | 5 | 6 | 5 | 6 | 5 | 6 |
| Medication (6) | 3 | 6 | 5 | 5 | 6 | 6 | 6 | 6 |
| Use of antimicrobials (4) | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 |
| Miscellaneous (8) | 4 | 6 | 3 | 6 | 4 | 6 | 5 | 6 |
| Total (102) (%) | 49 (48.0%) | 88 (86.3%) | 59 (57.8%) | 83 (81.4%) | 59 (57.8%) | 84 (82.4%) | 61 (59.8%) | 85 (83.3%) |

IPC, infection prevention and control; ARM, antimicrobial-resistant micro-organisms.

deficits in hand hygiene infrastructure (a subgroup of the audit category 'hand hygiene') at baseline (e.g. a lack of handwashing stations with soap, and hand disinfection in areas with patient contact). Additionally, deficits in cleaning and disinfection (e.g. the wrong application or insufficient coverage with the used product) were observed. All clinics had insufficient general IPC management in place at baseline, with Clinic 2 achieving the lowest score for this category at baseline and after the intervention (Table II).

None of the clinics, apart from Clinic 4, had written protocols in place. Clinics 1 and 2 had inadequate isolation measures for infectious patients, and personal protective equipment was insufficient in Clinic 1. After the intervention, Clinic 1 achieved an improvement in the audit score. Successful implementation of IPC guidelines was achieved in all clinics. Food and beverages were removed from patient areas completely, general IPC management was introduced, isolation measures were improved, written protocols for cleaning/disinfection and isolation measures were introduced, and cleaning and disinfection products were adapted to the specific requirements of the clinic. Difficulties were experienced for the installation of sufficient hand hygiene equipment. Handwashing stations were not present in all examination rooms after the intervention, and construction of more stations was not always feasible. New hand hygiene disinfection stations were mounted in all participating clinics, but were still lacking in Clinic 2 after the intervention.

## *Hand hygiene compliance before and after intervention*

In total, 5116 hand hygiene observations were carried out. Of these, 90 observations were classified as 'non-coded' (i.e. none of the five moments for hand hygiene could be allocated to the observation), leaving 5026 observations to be included in the statistical analysis. The hand hygiene compliance for each clinic and grouped by professional group, indication and clinical area is shown in Table S2 (see online supplementary material). Overall, mean hand hygiene compliance was 20.9% (95% CI 19.2—22.8%) before the intervention, 42.5% (95% 40.4—44.7%) at 1-month follow-up, and 38.7% (95% CI 35.7—41.7%) at 5-month follow-up. Hand hygiene improved in all clinics after training, and also at 5 months (Figure 2). Hand hygiene was lowest in Clinic 2 at baseline (14.9%, 95% CI 12.1—18.2%) and one month after the intervention (30.5%, 95% CI 26.6—34.6%).

When looking at the professional groups in the four clinics, an increase in mean hand hygiene compliance was achieved in veterinarians in all clinics after the intervention, and this improvement was still present at 5-month follow-up (Figure 3). In contrast, the nurses showed an increase in mean hand hygiene compliance in Clinics 1 and 4 only.

Regarding the five hand hygiene indications, compliance was lowest before clean/aseptic procedures at baseline in all four clinics (Figure 4), After body fluid exposure risk was amongst the best performing indications at baseline and after the intervention in all clinics.

Hand hygiene was lowest in the pre-operative preparation area at baseline (Figure 5). After the intervention, hand hygiene compliance increased in the pre-operative preparation area, and this was the best performing area in Clinics 2 and 4.

## *Staff feedback on IPC intervention*

The summarized responses of the questionnaires sent to the staff of Clinics 1—4 can be found in Table S3 (see online supplementary material). In total, 37 completed questionnaires were available for analysis. The personnel gave the general hygiene practices in their clinic a median score of 5 (range 0—9) at baseline and 7 (range 2—10) after the intervention. Hand hygiene compliance received a median score of 5 (range 2—9) before the intervention and 7 (range 3—10) after the intervention. The quality of cleaning and disinfection received a median score of 6 (range 0—9) before the intervention and 7 (range 4—10) after the intervention. The practicability of the

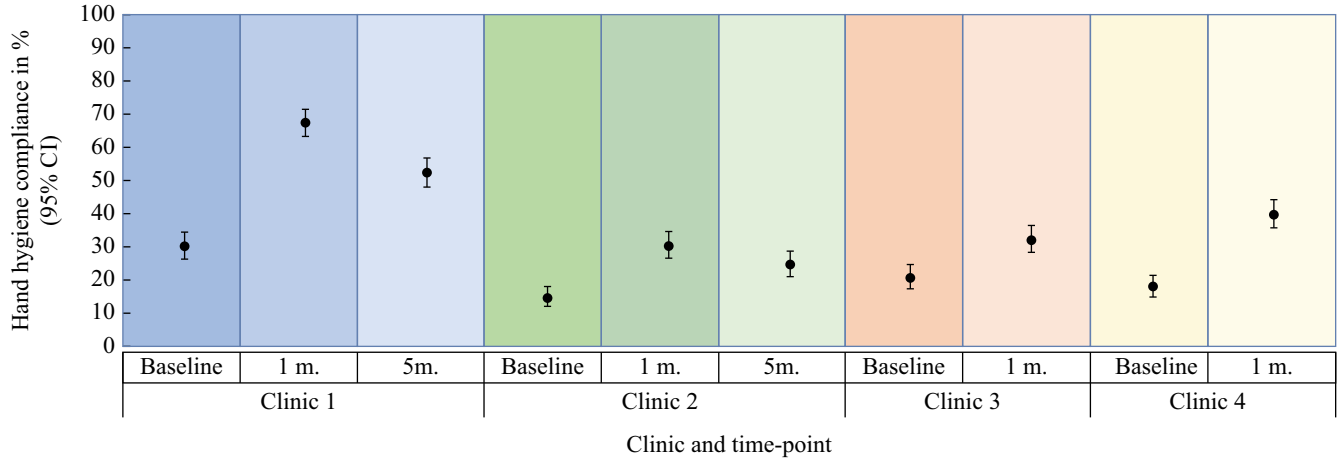


**Figure 2.** Mean hand hygiene compliance (%) with 95% confidence intervals (CI) in Clinics 1—4 at baseline, 1-month follow-up (1m; all clinics) and 5-month follow-up (5m; two clinics).

hand hygiene practices, the implemented cleaning and disinfection protocols and the isolation measures all had median scores of 7 (ranges 1—10, 1—10 and 2—10, respectively). The quality of the lectures received a median score of 8 (range 0—10). Overall, 70% of the respondents expressed the wish to receive additional education on hand hygiene and other hygiene practices. Additionally, 51% and 49% requested further education on prudent antimicrobial use and zoonoses, and ARM, respectively.

## Discussion

This study found generally low IPC practices in four companion animal clinics in Switzerland before the introduction of comprehensive IPC guidelines. At baseline, the clinics reached 48—60% of the maximum IPC score in the audit, which is in agreement with a previous study from Switzerland, where three companion animal clinics reached 28—52% of the maximum IPC score [19]. As in the previous study [19], CPE contamination was detected in one companion animal clinic in this study (Clinic 2): a total of 15.5% and 11.5% of the environmental swabs tested positive for ARM and CPE, respectively, at the baseline evaluation in this clinic. The dissemination of OXA-48 CPE in this clinic is particularly worrisome as CPE is considered an 'urgent' public health threat, as a case fatality rate of up to half of cases has been documented in human infections [51,52]. The finding that two of nine companion animal clinics in Switzerland examined in the two studies by the present authors showed massive environmental contamination with ESBL-E, CPE and meticillin-resistant *S. pseudintermedius* is alarming [10,19]. It highlights the rapid emergence of CPE and other ARM of public health concern in companion animal medicine [2]. The authors' previous studies also documented a high rate of acquisition of CPE by patients during hospitalization in the clinic [2], and the colonization of employees with epidemic clones of CPE closely related to environmental and patient-derived isolates [23]. This underlines the lack of efficient IPC practices to break transmission chains between patients, staff and the clinical environment in these settings [2,19,23].

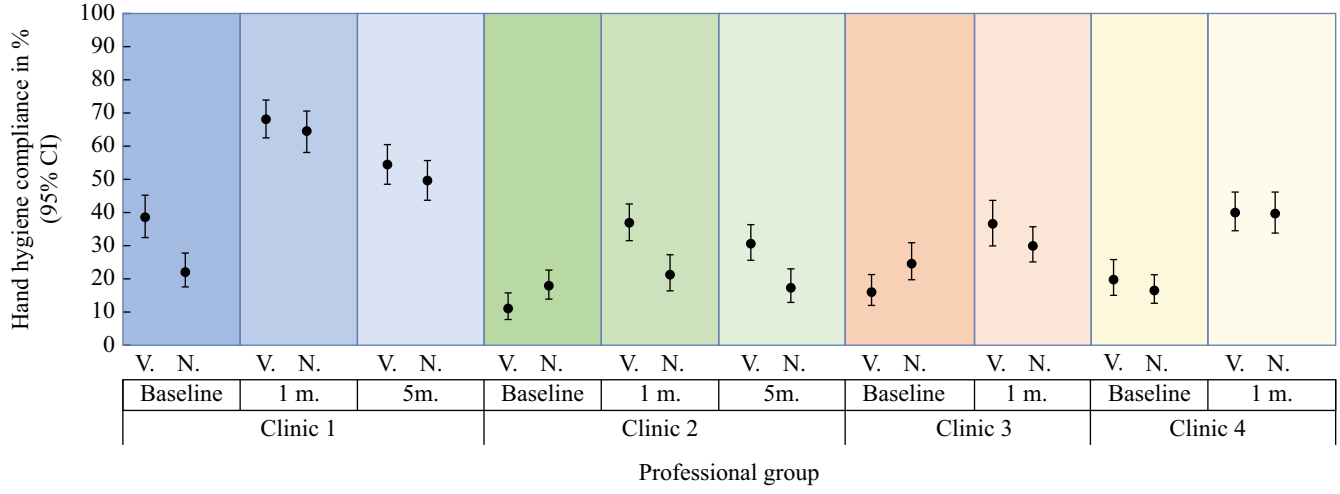


**Figure 3.** Mean hand hygiene compliance (%) with 95% confidence intervals (CI) in veterinarians and nurses in Clinics 1—4 at baseline, 1-month follow-up (1m; all clinics) and 5-month follow-up (5m; two clinics).V, veterinarians; N, nurses.

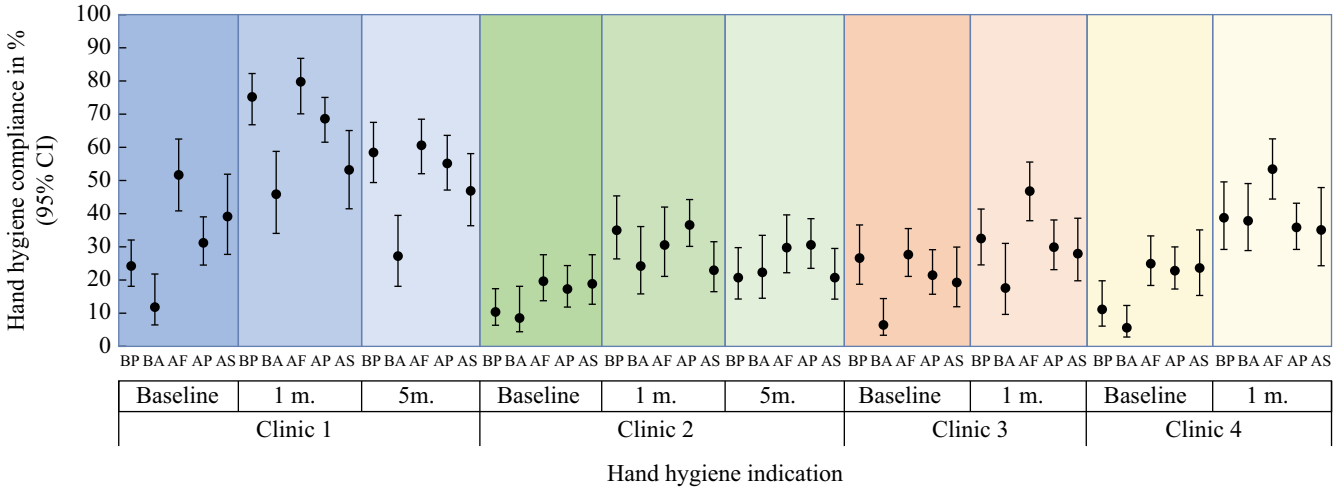


**Figure 4.** Mean hand hygiene compliance (%) with 95% confidence intervals (CI) according to hand hygiene indication in Clinics 1—4 at baseline, 1-month follow-up (1m; all clinics) and 5-month follow-up (5m; two clinics). BP, before patient contact; BA, before clean/aseptic procedures; AF, after body fluid exposure risk; AP, after patient contact; AS, after touching the patient surroundings.

There is thus an urgent need to foster IPC and to investigate the effect of IPC interventions on IPC standards, environmental contamination with ARM, and hand hygiene in companion animal clinics.

After a multi-modal IPC intervention, the IPC scores in all four clinics improved and the clinics achieved similarly high scores (81—86% of the maximum score) at 1-month follow-up. During the intervention, a special focus was set on written surface disinfection protocols and written isolation protocols, on the adaptation of the cleaning and disinfection products in the clinic, and the addition of hand hygiene equipment in the patient areas. With these measures, ARM contamination in Clinics 1, 3 and 4 was undetectable after the intervention. Furthermore, an increase in cleaning frequency, as evaluated by fluorescent tagging, was evident in all clinics. In contrast to Clinics 1, 3 and 4, the intervention was not successful in reducing or eliminating the extensive ARM contamination in the clinical environment in Clinic 2. The IPC scoring system did not really capture these failures in Clinic 2 at baseline or after the intervention. The continuous presence of $bla_{\text{OXA-48}}$ may point towards a common source of contamination in this clinic. A temporary patient stop to perform extensive cleaning and disinfection of all surfaces and utensils in the clinic prior to IPC intervention may have been necessary to combat the outbreak in this institution. The IPC intervention performed in this study may not have been sufficient to address an outbreak situation.

The IPC score used in this study was based on an audit protocol published as part of the AAHA infection control, prevention and biosecurity guidelines [21]. The protocol captures 15 areas of general IPC and is not specifically tailored to assess and combat ARM. The protocol may need to be adapted for future use to identify clinics with potential ARM dissemination. For instance, certain aspects (e.g. equipment and utensils on critical surfaces; number of hand hygiene dispensers, cleaning

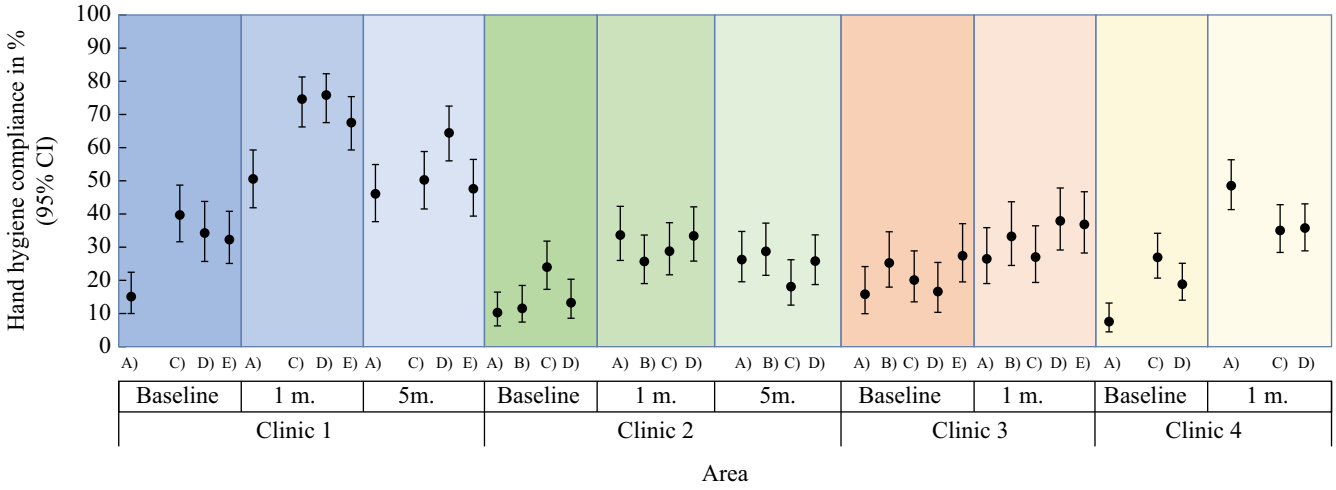


**Figure 5.** Mean hand hygiene compliance (%) with 95% confidence intervals (CI) according to clinical area in Clinics 1—4 at baseline, 1-month follow-up (1m; all clinics) and 5-month follow-up (5m; two clinics). An intensive care unit (ICU) was not present in Clinics 1 and 4, and an examination area was not present in Clinics 2 and 4. A, pre-operative preparation area; B, ICU; C, wards; D, consultation area; E, examination area.

frequency and handwashing stations) may need to be introduced into future scoring systems. Clinic 2, which showed severe ARM contamination, achieved among the lowest scores in the areas of general IPC management, cleaning and disinfection, hand hygiene, and isolation measures. Hand hygiene infrastructure was absent in several animal patient areas in this clinic. Furthermore, observations during the audits revealed that the clinic was less organized and cleaned-up in comparison to the other clinics. Many surfaces in critical areas such as the pre-operative preparation area were occupied by equipment and utensils which hampered cleaning and disinfection in these areas. Staff members also used hip pockets (taille organizers) to store utensils such as scissors during daily work. Such practice was observed previously in a companion animal clinic with a severe CPE outbreak [19]. These hip pockets belong to the staff, are not cleaned regularly, and could thus contribute to ARM transmission chains. Furthermore, baseline hand hygiene compliance of the clinical staff of Clinic 2 was the lowest among all participating clinics, with overall compliance of only 15%. Many of these critical aspects could not be fully addressed during the IPC intervention in Clinic 2. When evaluating IPC interventions in companion animal clinics in the future, particular attention should be paid to general IPC management, general cleaning status, cleaning and disinfection protocols, hand hygiene equipment in patient areas, and hand hygiene compliance to better identify clinics with a high risk of ARM dissemination.

Previous studies have shown that animal-contact surfaces are often cleaned more frequently than hand-contact surfaces in small animal hospitals [24,53]. In this study, all clinics showed deficits in cleaning and disinfection. In accordance with a recent study [54], ARM were detected on surfaces with and without patient contact. This highlights the need to focus on hand hygiene and adequate cleaning and disinfection protocols, not only of surfaces that come into contact with patients, but also those that are touched solely by personnel. A recent publication showed that fluorescent tags could be used effectively to assess environmental cleaning [24]. In this study, fluorescent tagging was used at baseline and after the intervention, and showed an increase in cleaning frequency in all clinics after the intervention. Fluorescent tagging may be more reliable in IPC assessment than the collection and culture of environmental swabs, as the latter is limited to the detection of defined ARM. However, neither IPC scoring nor fluorescent tagging was able to point towards the critical situation in Clinic 2, and environmental swabs may still be indicated when ARM outbreak situations are suspected.

In agreement with previous studies, this study found insufficient hand hygiene compliance in veterinary staff in companion animal clinics in Switzerland, with mean compliance of 21% before hand hygiene training. Previous studies reported hand hygiene compliance of 26—47% [31,37]. In this study, hand hygiene compliance increased from 21% at baseline to 43% at 1-month follow-up and 39% at 5-month follow-up; this documents that a significant and prolonged effect on hand hygiene can be achieved in veterinary staff by education and training. The decrease in hand hygiene compliance at 5-month follow-up compared with 1-month follow-up may indicate that repetitive training of the staff, at least every 12 months [21], may be required to maintain compliance. It was, however, interesting that this hand hygiene campaign improved hand hygiene compliance primarily in veterinarians, whereas the effect was much less pronounced in veterinary nurses. Hand hygiene compliance in veterinarians improved in all clinics after the intervention, whereas this was only achieved in two clinics in nurses. This is in contrast to studies in human hospitals which reported that nurses respond better to hand hygiene training than doctors [36,55,56]. In our study, all staff members received the same teaching as part of the IPC intervention. The results indicate that the hand hygiene lectures and training need to be better adapted to the nursing staff, and that separate training lessons may be required for these two professional groups.

Hand hygiene was lowest in the pre-operative preparation area at baseline, and in the ICU after the intervention. Such areas with a high activity index (i.e. many opportunities for hand hygiene per hour) are prone to low hand hygiene compliance [57]. These results go in line with previous studies which documented lower compliance in these critical areas [31,37]. The WHO's five moments for hand hygiene guideline was originally developed for stationary patient areas in hospitals, which allowed clear identification of a patient area that needs to be protected [34]. In high activity areas, such as ICUs or pre-operative preparation areas, such patient areas are less clearly defined. Furthermore, the high activity index makes adherence to the five moments for hand hygiene more difficult. However, good hand hygiene is of particular importance in such high-traffic and high-risk environments, as there is increased risk for ARM contamination and transmission [19,58].

In agreement with previous studies in veterinary clinics, hand hygiene compliance was lowest before clean/aseptic procedures, and high after patient contact and after body fluid exposure risk [26,28,37], indicating that hand hygiene is often performed mainly for self-protection purposes. A similar pattern has been observed in human medicine where 'before clean/aseptic procedures' is the indication with the lowest compliance, and 'after patient contact' and 'after body fluid exposure risk' are the indications with the highest hand hygiene compliance [56,59]. After the intervention, 'before clean/aseptic procedures' remained the indication with the lowest compliance, but hand hygiene 'before touching a patient' became the second-best-performing indication. This may indicate that the indication 'before patient contact' is easier to teach and to put into practice than 'before clean aseptic procedures'. The present results contrast with a study from human medicine that found no change in the hand hygiene indication pattern after training. However, a study in veterinary medicine showed that the presence of posters had a significant effect on hand hygiene 'before patient contact' and 'before clean/aseptic procedures' [28].

The present study has limitations. First, the IPC scoring system, although carried out by two people, may be subjective to interpretation. Additionally, the Hawthorne effect may have caused overestimation of the hand hygiene results, as direct observation may lead to higher compliance [60,61]. This effect may have been more pronounced after the IPC intervention. To address this bias, a large number of observations were made over prolonged periods of time and as discreetly as possible, because studies have shown that the Hawthorne effect is transient and decreases over time and with an increasing number of observations [38]. Furthermore, only four clinics were included in the present study. Thus, the results may not be generally applicable to other clinics. In addition, the microbiological analyses at baseline were interrupted due to

the COVID-19 pandemic, and thus these microbiological samples were collected a relatively long time before the IPC intervention started. However, environmental contamination with ARM was low in Clinics 1, 3 and 4 before and after the intervention, and no decrease was observed in Clinic 2 which showed extensive ARM contamination. All other data (IPC audit scoring, hand hygiene evaluation, fluorescent tagging) were collected or reconfirmed directly before development and implementation of the IPC guidelines, when most COVID-19 measures had been lifted. Furthermore, given the very low environmental contamination with ARM at baseline in three of the clinics, the question to which extent the IPC intervention impacted the clinics at a microbiological level cannot be answered fully by this study. The study focused on selected ARM, so the possibility that an effect on other pathogens or on hospital-acquired infections was present but missed due to the study set-up cannot be excluded. Finally, the final follow-up was conducted 5 months after the intervention, and it remains unclear whether the positive effect of the IPC intervention continued beyond this time.

In conclusion, this study identified low IPC practices in companion animal clinics in Switzerland, and extensive environmental contamination with ARM of public health concern in one of the clinics. The IPC intervention was successful in improving general IPC practices and hand hygiene compliance in all clinics. However, environmental contamination remained high in the clinic with massive CPE spread. This may indicate that clinics with extensive contamination may require more targeted interventions to improve IPC and omit ARM spread. The hand hygiene campaign improved hand hygiene in the veterinary staff in all of the participating clinics. Hand hygiene represents the most effective measure to break transmission chains in clinical settings. The effect lasted for at least 5 months after the intervention, but was more pronounced in veterinarians than in nurses. The results of this study could lay the basis for minimal requirements for IPC practices for companion animal clinics in Switzerland as part of national strategies to combat the spread of ARM at the companion animal—veterinary clinic—human interface.

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**Conflict of interest statement**
None declared.

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**Author contributions**
RS, BW and KD contributed to the design of the study. KD conducted the sampling and data collection, BW and KD performed the IPC audits, KD and BW planned and supported the IPC intervention, and KD held hand hygiene and IPC education. RS, KZ and KD isolated and identified the strains and performed the microbiological work. RS, KZ and KD interpreted the bacteriological and molecular data, and BW and KD interpreted the IPC and hand hygiene data. KD wrote the manuscript, and RS and BW edited the manuscript. This study was part of the PhD project of KD. All authors reviewed and approved the final version of the manuscript.

## Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jhin.2023.06.002.

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