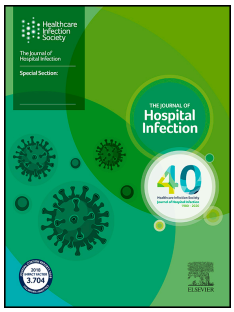

Educational intervention to improve infection prevention and control practices in four companion animal clinics in Switzerland

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

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Abstract

Infection prevention and control (IPC) practices vary among companion animal clinics and outbreaks with carbapenemase-producing Enterobacterales (CPE) have been described. This study investigates the effect of an IPC intervention (introduction of IPC protocols, IPC lectures, hand hygiene campaign) in four companion animal clinics. IPC practices, environmental and hand contamination with antimicrobial-resistant microorganisms (ARM) and hand hygiene (HH) were assessed at baseline and one and five months after intervention. IPC scores (% maximum score) improved from (median, range) 57.8% (48.0–59.8%) to 82.9% (81.4–86.3%) one month after intervention. Cleaning frequency assessed by fluorescent tagging increased from (median, range) 16.7% (8.9–18.9%) to 30.6% (27.8–52.2%) one months and 32.8% (32.2–33.3%) five months after intervention. ARM contamination was low in three clinics at baseline and undetectable after intervention. One clinic showed extensive contamination with ARM including CPE before and after intervention (7.5–15.5% ARM-positive and 5.0–11.5% CPE-positive samples). Mean HH compliance [95% CI]

improved from 20.9% [19.2–22.8%] to 42.5% [40.4–44.7%] one and 38.7% [35.7–41.7%] five months after intervention. Compliance was lowest in the pre-operating preparation area at baseline (11.8% [9.3–14.8%]) and in the ICU after intervention (28.8% [23.3–35.1%]). HH compliance was similar in veterinarians (21.5% [19.0–24.3%]) and nurses (20.2% [17.9–22.7%]) at baseline but higher in veterinarians (46.0% [42.9–49.1%]) than nurses (39.0% [36.0–42.1%]) one month after intervention. The IPC intervention improved IPC scores, cleaning frequency and HH compliance in all clinics. Adapted approaches might be needed in outbreak situations.

Introduction

The emergence of antimicrobial-resistant microorganisms (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 challenges 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 are faced with 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 might foster the development and spread of ARM. Animal patients receive invasive procedures similar like 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 healthcare 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 hospitalisation costs, and increased patient and staff satisfaction. The World Health Organization (WHO) established Guidelines on Core Components of Infection Prevention and Control Programs to be implemented at the 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 also to private clinics and practices. Guidelines on IPC in companion animal medicine have been published, but since 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 environment of the clinics 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 since many high-touch surfaces are not cleaned in a frequent and adequate manner [16,24].

Hand hygiene is regarded 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 enhanced 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 adherence dropped again after six months, hand hygiene adherence was still above baseline [29]. The studies used different techniques to define and evaluate hand hygiene and results are thus difficult to compare. 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 healthcare in the 1980s [32,33]. The WHO offers a comprehensive multimodal 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 with its 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 microorganisms. The WHO guidelines define “Five moments for hand hygiene”, which represent hand hygiene indications for healthcare workers with the goal to prevent the introduction of microorganisms by the hand of healthcare workers into the patient zone, between critical sites within the patient zone, and the spread of

105 microorganisms from the patient zone to the healthcare area. According to these
106 guidelines, hand hygiene should be applied 1) before patient contact, 2) after body fluid
107 exposure risk, 3) after touching the patient surrounding, 4) before clean/aseptic
108 procedures and 5) after patient contact. Both hand disinfection, i.e. the use of alcohol-
109 based hand sanitizer, and washing the hands with water and soap are considered hand
110 hygiene procedures [35]. Teaching and promoting these guidelines to healthcare
111 workers can remarkably improve hand hygiene compliance in human hospitals and
112 decreased the rate of nosocomial, i.e. hospital acquired, infections by almost 50%
113 [34,36]. The WHO guidelines were recently applied to investigate hand hygiene
114 compliance in companion animal clinics and practices in Switzerland, and a hand
115 hygiene compliance of the veterinary staff ranging from 26% to 47% was found. Hand
116 hygiene compliance was lowest before clean/aseptic procedures, and highest after
117 body fluid exposure risk [31,37].
118 No study has yet assessed whether a multimodal IPC intervention can improve IPC
119 practices and hand hygiene compliance and reduce environmental contamination with
120 ARM in companion animal clinics. The present study assesses baseline IPC practices,
121 hand hygiene compliance, hand contamination of the veterinary staff, cleaning
122 frequency and environmental contamination with CPE, ESBL-E, MRS and
123 vancomycin-resistant enterococci (VRE) in four companion animal clinics in
124 Switzerland. Each clinic was then part of a multimodal IPC intervention that comprised
125 1) the recruitment of an infection control preventionist, 2) the implementation of written
126 IPC guidelines, 3) the introduction of written cleaning/disinfection and isolation
127 protocols throughout the clinic, and 4) a comprehensive hand hygiene campaign that
128 included a lecture, hand hygiene posters, practical hand hygiene trainings and
129 observation-feedback sessions. After the intervention, the above-mentioned

evaluations were repeated one (four clinics) and five months later (two clinic) and results compared to baseline values.

Material and Methods

Study set-up

Four private companion animal clinics (Clinics 1–4) located in three different geographic regions of Switzerland (east, west, 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-hour 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 that 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 free of charge IPC evaluations 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 IPC implementation, and support in the development of IPC guidelines and written protocols and cleaning/disinfection and isolation measures.

The study set-up and the timeline of the study are shown in Supplementary Figure S1. Due to a study interruption caused by the 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 re-checked again between July 2021 and August 2021 (before IPC intervention development) and scores adapted if necessary. Baseline hand hygiene evaluations and fluorescent tagging were

156 performed from July 2021 to August 2021 after COVID-19 restrictions had been lifted
157 in Switzerland. Thereafter, the clinic-specific IPC interventions were developed
158 (August 2021 to January 2022) with the selected infection control preventionist for each
159 clinic. The multimodal IPC interventions were introduced to the staff and lectures and
160 hand hygiene trainings were held between January 2022 and April 2022; the IPC
161 intervention took one week per clinic. Clinics 1–4 were re-evaluated one month after
162 intervention (April 2022 to July 2022) using the same methodology as for the
163 establishment of the baseline data. In Clinics 1 and 2 (the best and the worst
164 performing one month after implementation, respectively), a second re-evaluation took
165 place five months after intervention (June 2022 and Sept 2022, respectively), to assess
166 the long-term effect of the intervention. The five months follow-up comprised evaluation
167 of hand hygiene compliance, cleaning frequency and environmental contamination
168 with ARM. Follow-up data of each clinic were compared to baseline data. Selected
169 results from the baseline evaluation of Clinic 2 have already been published [10].
170
171 *IPC evaluation by direct audit*
172 IPC practices in Clinics 1–4 were evaluated by a one-day direct audit by two of the
173 authors (KD, BW) and a adapted IPC audit protocol comprising fifteen areas of IPC
174 was applied [10,21]. The IPC audit protocol was originally published as part of the
175 American Animal Hospital Association (AAHA) Infection Control, Prevention, and
176 Biosecurity Guidelines. The audit assessed general IPC management, staff education,
177 cleaning/disinfection, management of waste, vector control, equipment in examination
178 rooms, isolation measures, handling of patients with ARM, hand hygiene equipment,
179 personal hygiene, protection of employees, protective clothing, medication, use of
180 antimicrobials and miscellaneous. A template for the audit has been published
181 previously [10]. A scoring system (0: not fulfilled; 1: partially fulfilled; 2 completely

fulfilled) was applied as previously described [19] and % 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 IPC implementation.

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 [31,37]. All hand hygiene observations were performed in-person by the same observer (KD). Based on previously obtained data [31,37], a hand hygiene compliance of 32% at baseline was assumed and a samples size for 500 hand hygiene events per clinic (100 observations per study area) were collected to allow to differentiate a 10%-difference in hand hygiene compliance before and after intervention [38]. All hand hygiene observations were carried out by the same observer (KD) who has previously evaluated hand hygiene for other studies 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 [31,37,38] and based on the WHO five moments for hand hygiene that are 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 hand washing 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-operating preparation area, the intensive care unit, 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, the data were extracted from the software as Excel files 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 were calculated using the hybrid Wilson/Brown method using the software GraphPad Prism (version 9.5.1 for Windows, GraphPad Software, San Diego, California USA) and hand hygiene compliance compared before and after 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 previously described [10,16]. A list of high-touch surfaces has been previously published [10]. In each clinic, the sampling was performed during the first half of the day on four different sampling days over a two-week period (50 samples per day) to account for daily variation in environmental contamination [16]. At the five-month follow-up in Clinic 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). Percentage of positive surfaces (before and after intervention)

with 95% confidence intervals was calculated using GraphPad Prism version 9.5.1 for Windows, GraphPad Software, San Diego, California USA.

Cleaning frequency

Fluorescent markers (DAZO™ Fluorescent Marking Gel, ECOLAB, Germany) were used as a non-cultural method to evaluate cleaning frequency in the clinics according to published methods [24]. A total of 90 surfaces from a list of 30 surfaces (Supplement Table S1, each surface was sampled thrice) were marked and re-evaluated for fluorescence after 24 hours. 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% confidence intervals was calculated and compared before and after intervention using GraphPad Prism version 9.5.1 for Windows, GraphPad Software, San Diego, California USA.

Hand contamination with ARM

A total of 20 hand swabs per clinic were collected from the veterinary staff at baseline sampling and at the one-month follow-up using previously described methods [10,31]. Briefly, hand swabs of the entire dominant hand palm, fingers, and thumb 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. Percentage of positive hand swabs with 95% confidence intervals was calculated and compared before and after intervention using GraphPad Prism version 9.5.1 for

Windows, GraphPad Software, San Diego, California USA. 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 according to standard protocols as previously described [10,31]. Swabs were processed within 12 hours after sample collection.

The homogenate of all samples was thereafter enriched (37 °C, 24 h), followed by selective enrichment for ESBL-E and CPE in Enterobacterales enrichment broth (Oxoid, Hampshire, UK), in BHI (BioRad, Hercules, CA, USA) with 6.5% saline for VRE, and additionally in Mueller Hinton broth (Oxoid, Hampshire, UK) with 6.5% saline, followed by anfingernails

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 by using the chromogenic medium Brilliance™ ESBL Agar (Oxoid, Hampshire, UK), CPE by using chromID® CARBA SMART Bi-Plate-Agar (bioMérieux, Marcy-l'Étoile, France), VRE by using the Brilliance™ VRE Agar (Oxoid, Hampshire, UK) and MRS by using the Brilliance™ MRSA2 Agar (Oxoid, Hampshire, UK), according to the manufacturer's instructions. Species identification was conducted by using matrix-assisted laser desorption/ionization time-of-flight mass spectrometry (MALDI-TOF–MS, 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 previously described [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, Balgach, Switzerland), as previously described [45,46].

Antimicrobial susceptibility testing was carried out for all ESBL-E and CPE isolates as previously described [16]. Antimicrobial susceptibility testing was performed for Enterobacterales in accordance with the Clinical and Laboratory Institute (CLSI) performance standards [47] using the disk-diffusion method on Mueller Hinton plates (Oxoid, Hampshire, UK) and the 16 antibiotics: ampicillin (AM), amoxicillin with clavulanic acid (AMC), azithromycin (AZM), cefazolin (CZ), cefepime (FEP), cefotaxime (CTX), chloramphenicol (C), ciprofloxacin (CIP), fosfomycin (FOS), gentamicin (G), kanamycin (K), nalidixic acid (NA), nitrofurantoin (F/M), streptomycin (S), sulfamethoxazole trimethoprim (SXT), and tetracycline (TE) (Becton Dickinson, Allschwil, Switzerland). Results were interpreted according to CLSI standards [47]. For azithromycin, an inhibition zone of ≤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, Marcy l'Etoile, France) 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 that 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 interest in IPC was selected. Comprehensive IPC guidelines written by the study

311 personnel and based on published protocols [48,49] were introduced in each clinic. If
312 IPC guidelines were already in place, these were used as a basis and adapted. The
313 focus of the intervention period was on adequate and written cleaning and disinfection
314 protocols, personnel hygiene (i.e. working clothes and shoes, no jewellery, no long or
315 artificial fingernails, no food consumption in patient areas, no storage of food of the
316 staff in refrigerators in patient areas, laundry guidelines), hand hygiene and hand
317 hygiene equipment, isolation measures, information dissemination among employees
318 and involvement of employees in IPC. The guidelines were adapted to fit the specific
319 needs and address as many IPC deficits identified during the baseline evaluation as
320 possible. If implementation of certain aspects was considered unfeasible, the guideline
321 was adapted. The final IPC guidelines were approved by the clinic directors. Written
322 cleaning and disinfection and isolation protocols were established for each clinic and
323 put up throughout the clinic. The IPC development and implementation in Clinics 1–4
324 was guided and supported by the authors of this study by regular meetings with the
325 infection control preventionists between August 2021 and January 2022. The IPC
326 interventions took place between January 2022 and April 2022 (one week per clinic).
327 The interventions included a half-day lecture hold by the first author to introduce the
328 IPC guidelines and cleaning/disinfection and isolation protocols to all staff members.
329 The lecture focused on the following topics: introduction on the importance of IPC in
330 veterinary clinics, WHO guidelines on hand hygiene (i.e. hand washing *vs.* hand
331 disinfection, correct use of gloves, hand hygiene in the clinical setting: my five moments
332 for hand hygiene), personnel hygiene, newly implemented cleaning and disinfection
333 protocols and isolation measures specific to each clinic.
334
335 The hand hygiene intervention comprised a hand hygiene campaign, including a
336 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 [50].

Staff feedback on IPC intervention

Barriers and facilitators for IPC implementation were qualitatively assessed using a questionnaire (Supplementary Table S2) sent by email to all staff members of the clinics (around 20–80 staff/clinic) after the IPC implementation. 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 intervention

Clinics 1–4 were based in three different parts of Switzerland. All clinics offered a 24-hour emergency service. Clinics 1 and 2 additionally had an intensive care unit (ICU). A summary of the IPC audit and microbiological results can be found in Table 1. Baseline sampling detected selected ARM (ESBL-E, CPE and/ or MRS) in all four clinics. Environmental contamination with ARM was however negligible in Clinics 1, 3 and 4 (range of ARM-positive swabs: 0–1.5%) and was undetectable in the follow-up evaluations (Table 1). Environmental contamination was extensive in Clinic 2 at baseline (15.5%), at one month (7.5%) and at five months after intervention (16.0%). Detailed microbiological results from the baseline evaluation in Clinic 2 have previously been published [10]. At the one-month follow-up, Clinic 2 showed a contamination with OXA-48 CPE (7.5%) and ESBL-E (0.5%) in the environmental samples.

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

Fluorescent tagging revealed that at baseline (median, range) 16.7% (8.9–18.9%) of surfaces were cleaned in Clinics 1–4 within 24 hours after fluorescent tagging. One and five months after intervention, 30.6% (27.8–52.2%) and 32.8% (32.2–33.3%) of surfaces, respectively, were cleaned within 24 hours.

IPC audit score before and after intervention

The percentage of the total IPC audit score at baseline ranged from 48% (Clinic 1) to 60% (Clinic 4, Table 1 and Figure 1). The IPC audit score of the clinics increased from (median, range) 57.8% (48.0–59.8%) to 82.9% (81.4–86.3%) one month after intervention. The IPC scores at one months were similar among the clinics (Table 1). Detailed results of the IPC audits are shown in Table 1. All clinics showed major deficits in hand hygiene infrastructure (a subgroup of the audit category hand hygiene) at baseline, e.g. a lack of washing 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 an insufficient general IPC management in place at baseline with Clinic 2 achieving the lowest score for this category at baseline and after intervention (Table 2).

None of the clinics, apart from Clinic 4, had written protocols in place. Clinics 1 and 2 additionally had inadequate isolation measures for infectious patients and personal protective equipment was insufficient in Clinic 1. After intervention, Clinic 1 achieved an improvement in the audit scoring. Successful implementation of IPC guidelines was achieved in all clinics. Food and beverages were completely removed from the patient

areas, a 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. Washing stations were not present in all examination rooms after 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 intervention.

Hand hygiene adherence 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 statistical analysis. Overall mean hand hygiene compliance [95% confidence interval] was 20.9% [19.2–22.8%] before intervention and 42.5% [40.4–44.7%] one month and 38.7% [35.7–41.7%] five months after intervention. Hand hygiene improved in all clinics after training, also at five months (Figure 2). Hand hygiene was lowest in Clinic 2 at baseline (14.9% [12.1–18.2%]) and after intervention (30.5% [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 intervention and this improvement was still present five months after intervention (Figure 3). In contrast, the nurses showed an increase in mean hand hygiene compliance only in Clinics 1 and 4.

Regarding the five hand hygiene indications, compliance was lowest before clean/ aseptic procedures at baseline in all four clinics (Figure 4) but increased after

intervention in all clinics except for Clinic 2. After body fluid exposure risk was amongst the best performing indications at baseline and after intervention in all clinics.

Hand hygiene was lowest in the pre-operating preparation area at baseline (Figure 5). After intervention, hand hygiene compliance increased in the pre-operating preparation area and 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 Supplementary Table S2. A total of 37 filled questionnaires were available for analysis. The personnel judged the general hygiene practices in their clinic (median, range) as a 5 (0–9) before and as a 7 (2–10) after intervention. The hand hygiene compliance was rated (median, range) a 5 (2–9) before and a 7 (3–10) after intervention. Quality of cleaning and disinfection was judged median (range) 6 (0–9) before and 7 (4–10) after intervention. The practicability of the hand hygiene practices, the implemented cleaning and disinfection protocols and the isolation measures were all rated (median, range) a 7 (1–10; 1–10 and 2–10, respectively). The quality of the lectures was rated (median, range) an 8 (0–10). Overall, 70% of the respondents expressed the wish to receive additional education on hand hygiene and other hygiene practices. Additionally, 51% also requested further education on prudent antimicrobial use and zoonoses, 49% on ARM.

Discussion

This study documents 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], a CPE contamination was detected in one companion animal clinic in this study (Clinic 2): a total of 15.5% of the environmental swabs tested positive for ARM and 11.5% for CPE at 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 since a case fatality rate of up to half of the cases has been documented in human infections [51,52]. The finding that two out of nine companion animal clinics in Switzerland examined in our two studies 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]. In our previous studies, we 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]. 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 multimodal IPC intervention, the IPC scores in all four clinics improved and the clinics achieved similarly high scores (81–86% of the maximum score) one month after intervention. During the intervention, a special focus was set on written surface disinfection protocols, 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 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 Clinic 2 in reducing or eliminating the extensive ARM contamination in the clinical environment. Our IPC scoring system did not really capture these failures in Clinic 2 at baseline and after intervention. The continuous presence of *bla*$_{\text{OXA-48}}$ might point towards a common source of contamination in this clinic. A temporary patient stop to perform an extensive cleaning and disinfection of all surfaces and utensils of the clinic prior to IPC intervention might have been necessary to combat the outbreak in this institution. The IPC intervention performed in this study might 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 American Animal Hospital Association (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 might need to be adapted for future use to identify clinics with potential ARM dissemination. For instance, certain aspects such as equipment and utensils on critical surfaces, the number of hand hygiene dispensers, cleaning frequency and hand washing stations might need to be introduced into future scoring systems. Clinic 2 which showed severe ARM contamination reached amongst 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 audit revealed that the clinic was generally less cleaned-up than the other clinics, and equipment and utensils were present on surfaces in critical areas such as the pre-operating preparation area, making cleaning and disinfection more difficult. Staff members also used hip pockets (taille organizers) to store utensils such as scissors during daily work. Such practice has previously also been observed in another companion animal clinic with a severe CPE outbreak [19]. These hip pockets belong to the staff, are not regularly cleaned and could thus

492 contribute to ARM transmission chains. Furthermore, the clinical staff of Clinic 2
493 showed one of the lowest baseline hand hygiene compliance with an overall adherence
494 of only 15%. Many of these critical aspects could not be fully addressed during IPC
495 intervention in Clinic 2. When evaluating IPC interventions in companion animal clinics
496 in the future, particular attention should be paid to general IPC management, general
497 cleaning status, cleaning and disinfection protocols, hand hygiene equipment in patient
498 areas and hand hygiene adherence to better identify clinics with a higher risk of ARM
499 dissemination.
500 Previous studies have shown that animal-contact surfaces are often cleaned more
501 frequently than hand-contact surfaces in small animal hospitals [24,53]. In this study,
502 all clinics showed deficits in cleaning and disinfection. In accordance with a recent
503 study [54], ARM were detected on surfaces with and without patient contact. This
504 highlights the need to focus on hand hygiene and adequate cleaning and disinfection
505 protocols not only of surfaces that come into contact with patients, but also of those
506 that are solely being touched by the personnel. A recent publication showed that
507 fluorescent tags could be effectively used to asses environmental cleaning [24]. In this
508 study, fluorescent tagging was used at baseline and after IPC intervention and showed
509 an increase in cleaning frequency in all clinics after intervention. Fluorescent tagging
510 might be more reliable in IPC assessment than the collection and culture of
511 environmental swabs, since the latter is limited to the detection of defined ARM.
512 However, neither IPC scoring nor fluorescent tagging was able to point towards the
513 critical situation in Clinic 2, and environmental swabs might still be indicated when ARM
514 outbreak situations are suspected.
515 In agreement with previous studies, we found insufficient hand hygiene compliance in
516 veterinary staff in companion animal clinics in Switzerland, with a mean adherence of
517 21% before the hand hygiene training. Previous studies reported a hand hygiene

compliance of 26% to 47% [31,37]. In this study, hand hygiene compliance increased from 21% before intervention to 43% one month and 39% five months after intervention, which documents that a significant and prolonged effect on hand hygiene can be achieved in veterinary staff by education and training. The decrease in adherence five months compared to one month after intervention might indicate that repetitive training of the staff, at least every twelve months [21] might be required to maintain compliance. It was however interesting that our hand hygiene campaign improved hand hygiene compliance primarily in veterinarians, whereas the effect was much less pronounced in veterinary nurses. Hand hygiene adherence in veterinarians improved in in all clinics after 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 this study, all staff members received the same teaching as part of IPC implementation. The results indicate that the hand hygiene lectures and training need to be better adapted to the nursing staff and that separate training lessons might be required for these two professional groups.

Hand hygiene was lowest in the pre-operating preparation area before and in the ICU after 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 document lower compliances in these critical areas [31,37]. The WHO five moments for hand hygiene guideline had originally been developed for stationary patient areas in hospitals which allow to clearly identify a patient area that needs to be protected [34]. In high activity areas such as ICUs or pre-operating preparation areas, such patient areas are less clearly defined. Furthermore, the high activity index makes adherence to the 5 moments for hand hygiene more difficult. However, a good hand hygiene is of particular importance in such high traffic

and high risk environments as there is an 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 purpose. A similar pattern is also 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" those with the highest hand hygiene compliance [56,59]. After 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 might indicate that the indication "before patient contact" is easier to teach and to put into practice than before clean aseptic procedures. Our results contrast with a study from human medicine that found no change in the hand hygiene indication pattern after training. A study in veterinary medicine however 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 also has its limitations. For one, the IPC scoring system, although carried out by two people, might be subjective to interpretation. Additionally, the Hawthorne effect may have caused an overestimation of the hand hygiene results as direct observation may lead to a higher compliance [60,61]. Particularly after IPC intervention, this effect might have been more pronounced. To address this bias, a large number of observations was carried out over prolonged periods of time and as discreet 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

might 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 relatively long 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 re-confirmed directly before the development and implementation of the IPC guidelines when most COVID-19 measures had already 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 cannot be fully answered by our study. The study focused on selected ARM, so it cannot be excluded that an effect on other pathogens or on hospital-acquired infections was present but missed due to the study set-up. Lastly, the final follow-up was conducted five months after intervention, and it remains unclear whether the positive effect of IPC implementation continued beyond this time.

Conclusion

The present 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 conducted IPC intervention was successful in improving general IPC practices and hand hygiene compliance in all clinics. Environmental contamination remained however 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 stuff in all participating clinics. Hand

596 hygiene represents the most effective measure to break transmission chains in clinical
597 settings. The effect after intervention lasted for at least five months but was more
598 pronounced in veterinarians than in nurses. The results of the study could lay the basis
599 for minimal requirements for IPC practices for companion animal clinics in Switzerland
600 as part of national strategies to combat the spread of ARM at the companion animal –
601 veterinary clinic – human interface.
602

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609

610 **Conflict of interest**

611 None declared.
612

613 **Authors’ contributions**

614 RS, BW and KD contributed to the design of the study. KD conducted the sampling
615 and data collection, BW and KD performed the IPC audits, KD and BW planned and
616 supported the IPC implementation and KD hold the hand hygiene and IPC educations.
617 RS, KZ and KD isolated and identified the strains and performed the microbiological
618 work. RS, KZ and KD interpreted the bacteriological and molecular data, BW and KD
619 the IPC and hand hygiene data. KD wrote the manuscript, and RS and BW edited the
620 manuscript. This study was part of the Ph.D. project of Kira Dassler. All authors
621 reviewed and approved the final version of the manuscript.

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Tables and Figures

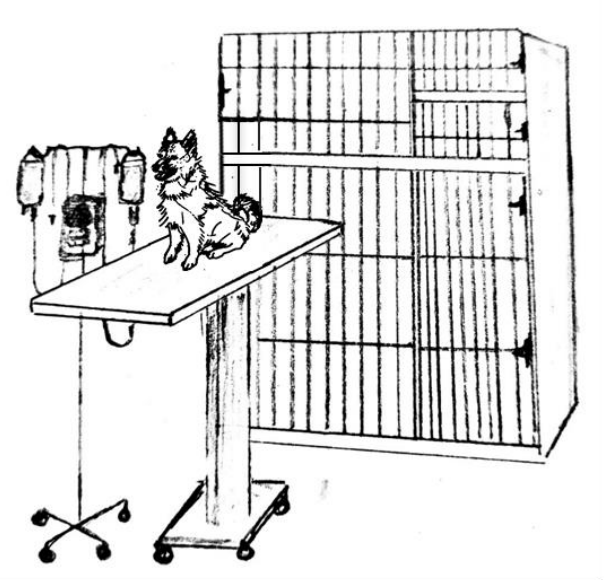

Figure 1. The patient and the patient zone comprising all areas that could potentially come into contact with the patient, such as the table, the ward, the infusion pump and IV lines.

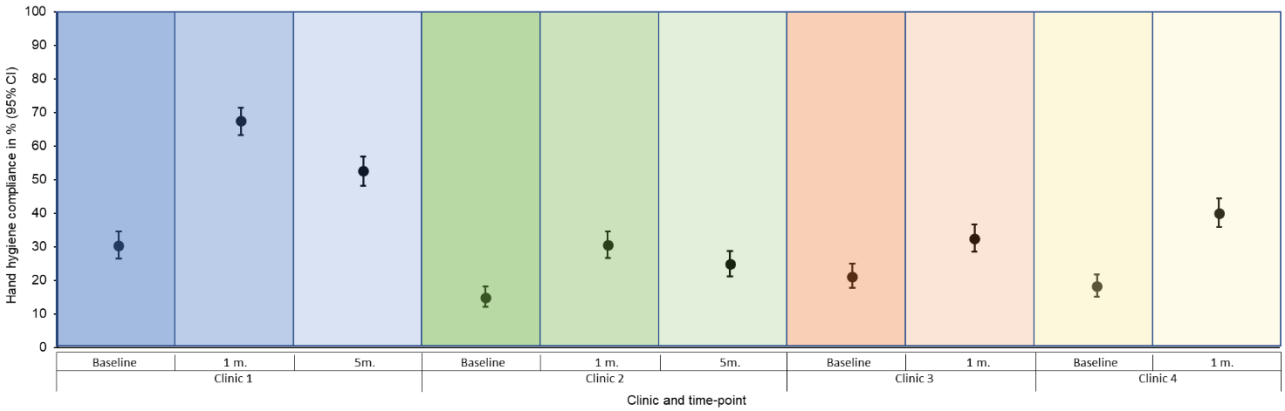

Figure 2. Mean hand hygiene compliance (%) with 95% confidence intervals in Clinics 1–4 at baseline and 1 month (all clinics) and 5 months (two clinics) after intervention. Abbreviations: 1m., one month follow-up; 5m., five-month follow-up

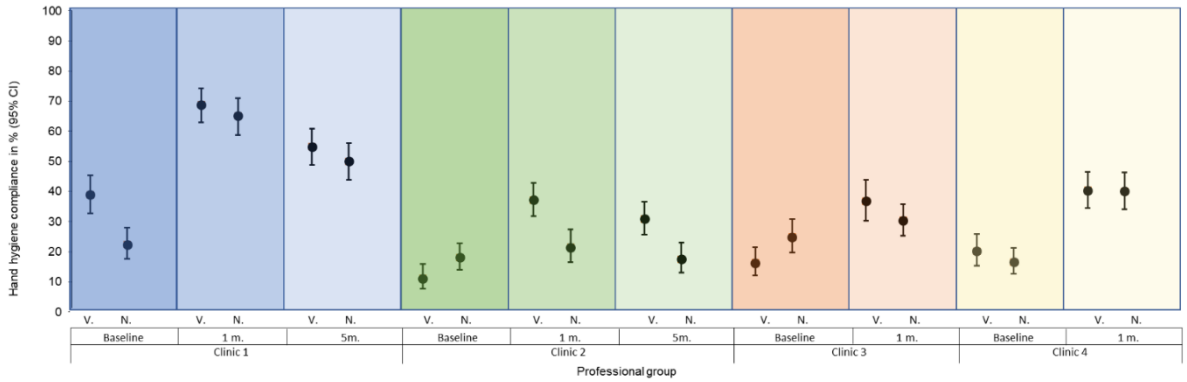

Figure 3. Mean hand hygiene compliance (%) with 95% confidence intervals in veterinarians and nurses in Clinics 1–4 at baseline and 1 month (all clinics) and 5 months (two clinics) after intervention.

Abbreviations: 1m., one month follow-up; 5m., five-month follow-up; V, veterinarian; N, nurse

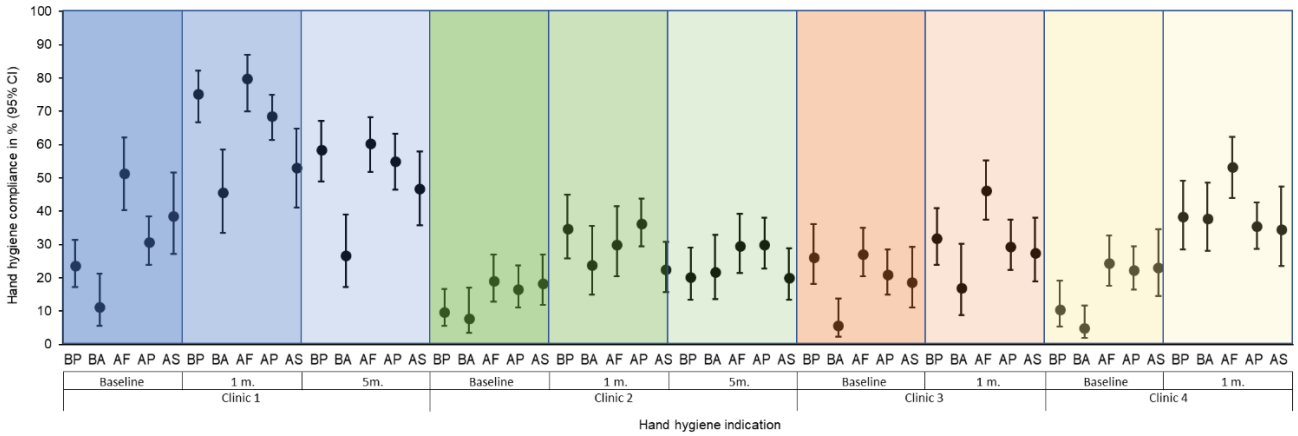

Figure 4. Mean hand hygiene compliance (%) with 95% confidence intervals according to hand hygiene indication in Clinics 1–4 at baseline and 1 month (all clinics) and 5 months (two clinics) after intervention.

Abbreviations: 1m., one month follow-up; 5m., five-month follow-up; BP, before patient contact; BA, before clean/aseptic procedures; AF, after body fluid exposure risk; AP, after patient contact; AS, after touching the patient surrounding

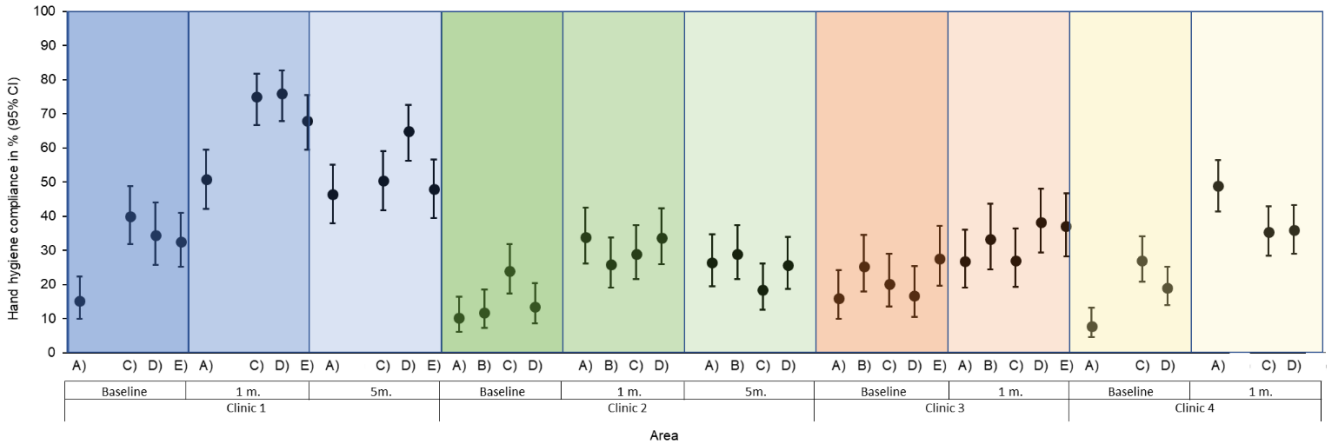

Figure 5. Mean hand hygiene compliance (%) with 95% confidence intervals according to clinical area in Clinics 1–4 at baseline and 1 month (all clinics) and 5 months (two clinics) after intervention. Intensive care unit was not present in Clinic 1 and 4, and examination area was not present in Clinic 2 and Clinic 4.

Abbreviations: 1m., one month follow-up; 5m., five-month follow-up; A), pre-operating preparation area; B), intensive care unit; C), wards; D), consultation area; E), examination area.

Table 1. Overview of the results from the audit, hand hygiene evaluation, ARM sampling and fluorescent tagging at baseline and one month and five months after intervention.

	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%]) 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%])	0% n= 20	0% n=20	n.a.	10%* [1.8–30.1] n=20	0% n=20	n.a.	10%* [1.8–30.1] n=20	0% n=20	0% n=20	0% n=20

and number of samples)										
ARM-positive environmental swabs (% [95%]) 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 % of total number of tags (90)	8.9%	52.2%	33.3%	16.7%	30.0%	32.2%	18.9%	31.1%	16.7%	27.8%

Abbreviations: HH, hand hygiene; ARM, antimicrobial resistant microorganisms

* Meticillin-resistant *Staphylococcus aureus* in all poitive hand swabs

Table 2. Results from the audit conducted in the four participating clinics at baseline and one month after intervention

	Clinic 1		Clinic 2		Clinic 3		Clinic 4	
Audit area (total score)	Baseline	1 month follow-up	Baseline	1 month follow-up	Baseline	1 month follow-up	Baseline	1 month follow-up
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	88	59	83	59	84	61	85
(%)	(48.0%)	(86.3%)	(57.8)	(81.4%)	(57.8%)	(82.4%)	(59.8%)	(83.3%)

Abbreviations: IPC, Infection prevention and control; ARM, antimicrobial resistant microorganisms; CI, confidence intervals