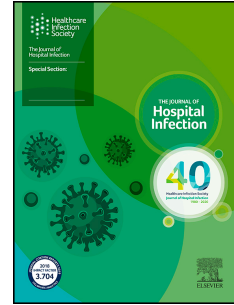


# Journal Pre-proof

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

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

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11

12 **Abstract**

13 Infection prevention and control (IPC) practices vary among companion animal clinics  
14 and outbreaks with carbapenemase-producing Enterobacterales (CPE) have been  
15 described. This study investigates the effect of an IPC intervention (introduction of IPC  
16 protocols, IPC lectures, hand hygiene campaign) in four companion animal clinics. IPC  
17 practices, environmental and hand contamination with antimicrobial-resistant  
18 microorganisms (ARM) and hand hygiene (HH) were assessed at baseline and one  
19 and five months after intervention. IPC scores (% maximum score) improved from  
20 (median, range) 57.8% (48.0–59.8%) to 82.9% (81.4–86.3%) one month after  
21 intervention. Cleaning frequency assessed by fluorescent tagging increased from  
22 (median, range) 16.7% (8.9–18.9%) to 30.6% (27.8–52.2%) one months and 32.8%  
23 (32.2–33.3%) five months after intervention. ARM contamination was low in three  
24 clinics at baseline and undetectable after intervention. One clinic showed extensive  
25 contamination with ARM including CPE before and after intervention (7.5–15.5% ARM-  
26 positive and 5.0–11.5% CPE-positive samples). Mean HH compliance [95% CI]

27 improved from 20.9% [19.2–22.8%] to 42.5% [40.4–44.7%] one and 38.7% [35.7–  
28 41.7%] five months after intervention. Compliance was lowest in the pre-operating  
29 preparation area at baseline (11.8% [9.3–14.8%]) and in the ICU after intervention  
30 (28.8% [23.3–35.1%]). HH compliance was similar in veterinarians (21.5% [19.0–  
31 24.3%]) and nurses (20.2% [17.9–22.7%]) at baseline but higher in veterinarians  
32 (46.0% [42.9–49.1%]) than nurses (39.0% [36.0–42.1%]) one month after intervention.  
33 The IPC intervention improved IPC scores, cleaning frequency and HH compliance in  
34 all clinics. Adapted approaches might be needed in outbreak situations.

35

## 36 **Introduction**

37 The emergence of antimicrobial-resistant microorganisms (ARM) is a major public  
38 health threat. Healthcare institutions play an important role in the transmission of ARM  
39 [1–6]. Over the past few years, the spread of highly critical drug-resistant organisms  
40 such as carbapenemase-producing Enterobacterales (CPE), endemic to countries  
41 such as Greece, Malta, Italy and Turkey challenges healthcare settings worldwide [7].  
42 Since 2010, CPE have been described in human healthcare settings in Switzerland  
43 [8]. Recently, several outbreaks comprising meticillin-resistant staphylococci (MRS),  
44 extended spectrum beta-lactamase-producing Enterobacterales (ESBL-E) and CPE  
45 have been documented in companion animal clinics, also in Switzerland [2,5,6,9,10].  
46 Besides ARM, companion animal clinics are faced with numerous highly contagious  
47 and zoonotic diseases [11] and transmission chains within these clinics can affect  
48 human and animal health [12–15]. Intensive medical care in small animal clinics might  
49 foster the development and spread of ARM. Animal patients receive invasive  
50 procedures similar like those in human hospitals and are treated with a variety of  
51 antimicrobials. Additionally, owners and their pets live in close contact within  
52 households, which promotes the transmission of pathogens, including ARM [16,17].

53 Infection prevention and control (IPC) guidelines are key elements in human  
54 healthcare to prevent the development and spread of ARM and other pathogens [18].  
55 The cornerstones of IPC guidelines are hand hygiene, staff education, personal  
56 protective equipment, adequate cleaning and disinfection, prudent use of  
57 antimicrobials and isolation measures [19–21]. Improvements in IPC practices result  
58 in better safety for patients and staff, reduced hospitalisation costs, and increased  
59 patient and staff satisfaction. The World Health Organization (WHO) established  
60 Guidelines on Core Components of Infection Prevention and Control Programs to be  
61 implemented at the national and acute human healthcare facility level [20]. Veterinary  
62 clinics and practices differ from human healthcare settings in relation to infrastructure,  
63 available resources, patient care and handling. Therefore, IPC guidelines for veterinary  
64 institutions need to be adapted and applicable also to private clinics and practices.  
65 Guidelines on IPC in companion animal medicine have been published, but since there  
66 is currently no legislation which regulates IPC practices in companion animal clinics  
67 and practices in Switzerland and other European countries, IPC implementation is  
68 optional and data on IPC in these settings are sparse. A previous study showed that  
69 IPC practices vary considerably across companion animal clinics and practices in  
70 Switzerland [19]. As a consequence, clinics with low IPC scores as evaluated by direct  
71 audits showed extensive environmental contamination with ARM, resulting in  
72 transmission opportunities to patients and staff. Hence, considerable colonization of  
73 patients with ARM during hospitalization was documented in extensively contaminated  
74 clinics [2,19,22]. These isolates included ARM of public health concern, such as MRS,  
75 ESBL-E and CPE [2,19,22]. Closely related ARM in patients, personnel and the  
76 environment of the clinics were documented, which underlines the need to break  
77 transmission chains by fostering IPC in these settings [2,23]. In addition to swab  
78 sampling, surface disinfection can also be evaluated with fluorescent tagging [24]. Both

79 methods have shown that there is a need to improve cleaning and disinfection in  
80 companion animal clinics since many high-touch surfaces are not cleaned in a frequent  
81 and adequate manner [16,24].

82 Hand hygiene is regarded a key element of IPC because stringent hand hygiene of  
83 healthcare workers is one of the most effective measures to interrupt transmission  
84 chains in healthcare settings [25]. Results from the few available studies on hand  
85 hygiene in companion animal veterinary institutions in the USA, Australia and Canada  
86 showed that compliance with hand hygiene guidelines was poor (14-27%), but could  
87 be enhanced up to 46% with hand hygiene campaigns [26–29]. Only one published  
88 abstract reported on the sustainability of the improvements and found that although  
89 hand hygiene adherence dropped again after six months, hand hygiene adherence  
90 was still above baseline [29]. The studies used different techniques to define and  
91 evaluate hand hygiene and results are thus difficult to compare. Other studies looked  
92 at hand contamination of veterinary staff and documented a variety of ARM on the  
93 hands of veterinary healthcare workers [10,30,31].

94 The first hand hygiene guidelines were introduced in human healthcare in the 1980s  
95 [32,33]. The WHO offers a comprehensive multimodal hand hygiene campaign for  
96 healthcare settings and the WHO Guidelines on Hand Hygiene in Health Care are well  
97 established in human hospitals [34]. The guidelines differentiate the patient zone (the  
98 patient with its immediate surroundings, Figure 1) from the healthcare area (all  
99 surfaces in the healthcare setting outside the patient zone). Within the patient zone,  
100 critical sites are defined, such as body sites or medical devices that must be protected  
101 against microorganisms. The WHO guidelines define “Five moments for hand  
102 hygiene”, which represent hand hygiene indications for healthcare workers with the  
103 goal to prevent the introduction of microorganisms by the hand of healthcare workers  
104 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

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

132

## 133 **Material and Methods**

### 134 *Study set-up*

135 Four private companion animal clinics (Clinics 1–4) located in three different  
136 geographic regions of Switzerland (east, west, central) were recruited by direct contact.

137 Participation was voluntary and was not reimbursed. Both clinics with and without pre-  
138 existing IPC guidelines were included. The study focused on companion animal clinics

139 (> 20 staff members, 24-hour emergency service and receiving first opinion and  
140 referred cases) in Switzerland. This decision was based on results of a previous study

141 in companion animal clinics and practices in Switzerland that indicated that despite low  
142 IPC scores in first opinion practices (as assessed by direct audit), environmental

143 contamination with ARM in first opinion practices was low [19]. The companion animal  
144 clinics were offered free of charge IPC evaluations by direct audits, evaluation of hand

145 hygiene compliance and hand contamination with ARM, evaluation of environmental  
146 contamination with ARM and assessment of cleaning frequency by fluorescent tagging

147 both before and after IPC implementation, and support in the development of IPC  
148 guidelines and written protocols and cleaning/disinfection and isolation measures.

149 The study set-up and the timeline of the study are shown in Supplementary Figure S1.

150 Due to a study interruption caused by the COVID-19 pandemic, the baseline  
151 microbiological evaluations took place between November 2019 and March 2020

152 (Clinics 1, 3 and 4) and again in September 2020 (Clinic 2). IPC audits were performed  
153 in the same period in each clinic, but results were re-checked again between July 2021

154 and August 2021 (before IPC intervention development) and scores adapted if  
155 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



182 fulfilled) was applied as previously described [19] and % of the total score (n= 102)  
183 was calculated. After baseline evaluation, the participating clinics received a written  
184 report of the audits, highlighting the IPC deficits and an action plan for IPC  
185 implementation.

186

### 187 *Hand hygiene compliance*

188 Hand hygiene compliance was assessed by direct observation using the CleanHands  
189 application (Swissnoso, National Centre for Infection Prevention, Bern, Switzerland)  
190 as described [31,37]. All hand hygiene observations were performed in-person by the  
191 same observer (KD). Based on previously obtained data [31,37], a hand hygiene  
192 compliance of 32% at baseline was assumed and a samples size for 500 hand hygiene  
193 events per clinic (100 observations per study area) were collected to allow to  
194 differentiate a 10%-difference in hand hygiene compliance before and after  
195 intervention [38]. All hand hygiene observations were carried out by the same observer  
196 (KD) who has previously evaluated hand hygiene for other studies and received prior  
197 training by an experienced human infection control practitioner at the University  
198 Hospital in Zurich, Switzerland [10,31]. Hand hygiene was evaluated as published  
199 [31,37,38] and based on the WHO five moments for hand hygiene that are described  
200 in detail in the WHO guidelines on hand hygiene in health care [34]. The five moments  
201 comprise “before touching a patient”, “before clean/ aseptic procedure”, “after body  
202 fluid exposure risk”, “after touching a patient”, and “after touching patient  
203 surroundings”. In accordance with the WHO guidelines, both hand disinfection with  
204 alcohol-based hand rubs and hand washing with water and soap but not the use of  
205 gloves were considered successful hand hygiene procedures [38]. The hand hygiene  
206 observations were conducted in five different areas of the clinics: the pre-operating  
207 preparation area, the intensive care unit, the wards, the consultation area, and the

208 examination area. If a certain area was not present in a clinic, the 500 observations  
209 were spread evenly across the existing areas. Additionally, three professional groups  
210 (veterinarians, nurses, others) were assessed. After recording, the data were extracted  
211 from the software as Excel files for statistical analyses. Non-coded hand hygiene  
212 observations, i.e., those that could not be matched to one of the five moments for hand  
213 hygiene, were excluded from analysis. Hand hygiene compliance (% of successful  
214 hand hygiene procedures per total number of observed hand hygiene observations)  
215 with 95% binomial confidence intervals were calculated using the hybrid Wilson/Brown  
216 method using the software GraphPad Prism (version 9.5.1 for Windows, GraphPad  
217 Software, San Diego, California USA) and hand hygiene compliance compared before  
218 and after intervention.

219

#### 220 *Environmental contamination with ARM*

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

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

235

### 236 *Cleaning frequency*

237 Fluorescent markers (DAZO™ Fluorescent Marking Gel, ECOLAB, Germany) were  
238 used as a non-cultural method to evaluate cleaning frequency in the clinics according  
239 to published methods [24]. A total of 90 surfaces from a list of 30 surfaces (Supplement  
240 Table S1, each surface was sampled thrice) were marked and re-evaluated for  
241 fluorescence after 24 hours. The sampled surfaces were not disclosed to the staff.  
242 Fluorescent tags and environmental sampling were conducted on the same day but  
243 independently of each other and thus did not impact one another. The percentage of  
244 successfully cleaned surfaces with 95% confidence intervals was calculated and  
245 compared before and after intervention using GraphPad Prism version 9.5.1 for  
246 Windows, GraphPad Software, San Diego, California USA.

247

### 248 *Hand contamination with ARM*

249 A total of 20 hand swabs per clinic were collected from the veterinary staff at baseline  
250 sampling and at the one-month follow-up using previously described methods [10,31].  
251 Briefly, hand swabs of the entire dominant hand palm, fingers, and thumb were  
252 collected from 20 veterinary staff members without announcement and immediately  
253 before and after patient contact using a sterile cotton swab moisturized with 0.85%  
254 saline solution. If gloves were worn, hand swabs were taken from the gloved hand. All  
255 swabs were analysed for the presence of ESBL-E, CPE, MRS and VRE. Participation  
256 of the employees was voluntary and written informed consent was obtained.  
257 Percentage of positive hand swabs with 95% confidence intervals was calculated and  
258 compared before and after intervention using GraphPad Prism version 9.5.1 for

259 Windows, GraphPad Software, San Diego, California USA. The study protocol was  
260 approved by the Swiss Ethics Committees on research involving humans (approval no.  
261 2019-00768).

262

### 263 *Microbiological evaluation*

264 Microbiological analysis of the samples was carried out according to standard  
265 protocols as previously described [10,31]. Swabs were processed within 12 hours after  
266 sample collection.

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

272 enrichment in tryptone soy broth (Becton Dickinson, Allschwil, Switzerland) with 4  
273 mg/L cefoxitin and 75 mg/L aztreonam for the detection of MRS. ESBL-E were  
274 screened by using the chromogenic medium Brilliance™ ESBL Agar (Oxoid,  
275 Hampshire, UK), CPE by using chromID® CARBA SMART Bi-Plate-Agar (bioMérieux,  
276 Marcy-l'Étoile, France), VRE by using the Brilliance™ VRE Agar (Oxoid, Hampshire,  
277 UK) and MRS by using the Brilliance™ MRSA2 Agar (Oxoid, Hampshire, UK),  
278 according to the manufacturer's instructions. Species identification was conducted by  
279 using matrix-assisted laser desorption/ionization time-of-flight mass spectrometry  
280 (MALDI-TOF-MS, Bruker Daltronics, Bremen, Germany).

281 Polymerase chain reaction (PCR) was carried out to screen for the presence of genes  
282 encoding *bla*<sub>CTX-M</sub> group enzymes, *bla*<sub>SHV</sub>, and *bla*<sub>TEM</sub>, as previously described [39–42].  
283 PCR targeting *bla*<sub>VIM</sub>, *bla*<sub>KPC</sub>, *bla*<sub>OXA-48-like</sub>, and *bla*<sub>NDM</sub> genes was carried out using  
284 custom synthesized primers (Microsynth, Balgach, Switzerland) and conditions

285 published previously [43,44]. PCR for the presence of *mecA* and *mecC* was conducted  
286 using custom synthesized primers (Microsynth, Balgach, Switzerland), as previously  
287 described [45,46].

288 Antimicrobial susceptibility testing was carried out for all ESBL-E and CPE isolates as  
289 previously described [16]. Antimicrobial susceptibility testing was performed for  
290 Enterobacterales in accordance with the Clinical and Laboratory Institute (CLSI)  
291 performance standards [47] using the disk-diffusion method on Mueller Hinton plates  
292 (Oxoid, Hampshire, UK) and the 16 antibiotics: ampicillin (AM), amoxicillin with  
293 clavulanic acid (AMC), azithromycin (AZM), cefazolin (CZ), cefepime (FEP),  
294 cefotaxime (CTX), chloramphenicol (C), ciprofloxacin (CIP), fosfomicin (FOS),  
295 gentamicin (G), kanamycin (K), nalidixic acid (NA), nitrofurantoin (F/M), streptomycin  
296 (S), sulfamethoxazole trimethoprim (SXT), and tetracycline (TE) (Becton Dickinson,  
297 Allschwil, Switzerland). Results were interpreted according to CLSI standards [47]. For  
298 azithromycin, an inhibition zone of  $\leq 12$  mm was interpreted as resistant. In addition,  
299 the minimal inhibitory concentrations of the carbapenem antibiotics ertapenem,  
300 imipenem, and meropenem were determined for all CPE isolates.

301 For MRS isolates, antimicrobial susceptibility profiling was performed using the  
302 automated VITEK<sup>®</sup> two compact system (bioMérieux, Marcy l'Etoile, France) with the  
303 AST-GP80 susceptibility testing card (bioMérieux, Nürtingen, Germany).

304

### 305 *Intervention*

306 An infection control preventionist (veterinarian or veterinary nurse) was elected from  
307 the existing staff and established in each clinic that was responsible for IPC  
308 implementation and future IPC maintenance. If possible, a person with a background  
309 in IPC was chosen. If such a person was not present, a veterinarian or veterinary nurse  
310 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

337 observation–feedback session [50]. Practical hand hygiene training performed with the  
338 staff used fluorescent hand disinfectant to train hand disinfection techniques.  
339 Observation feedback sessions were carried out as published [50].

340

#### 341 *Staff feedback on IPC intervention*

342 Barriers and facilitators for IPC implementation were qualitatively assessed using a  
343 questionnaire (Supplementary Table S2) sent by email to all staff members of the  
344 clinics (around 20–80 staff/clinic) after the IPC implementation. The questionnaire  
345 addressed possible barriers and facilitators for implementation and execution of IPC,  
346 the quality of the given lectures and an opportunity for the personnel to express  
347 constructive criticism. The personnel were asked to respond on a scale from 0 (very  
348 bad) to 10 (excellent).

349

## 350 **Results**

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

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

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

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

371

#### 372 *IPC audit score before and after intervention*

373 The percentage of the total IPC audit score at baseline ranged from 48% (Clinic 1) to  
374 60% (Clinic 4, Table 1 and Figure 1). The IPC audit score of the clinics increased from  
375 (median, range) 57.8% (48.0–59.8%) to 82.9% (81.4–86.3%) one month after  
376 intervention. The IPC scores at one months were similar among the clinics (Table 1).

377 Detailed results of the IPC audits are shown in Table 1. All clinics showed major deficits  
378 in hand hygiene infrastructure (a subgroup of the audit category hand hygiene) at  
379 baseline, e.g. a lack of washing stations with soap and hand disinfection in areas with  
380 patient contact. Additionally, deficits in cleaning and disinfection, e.g. the wrong  
381 application or insufficient coverage with the used product, were observed. All clinics  
382 had an insufficient general IPC management in place at baseline with Clinic 2 achieving  
383 the lowest score for this category at baseline and after intervention (Table 2).

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



389 areas, a general IPC management was introduced, isolation measures were improved,  
390 written protocols for cleaning/disinfection and isolation measures were introduced and  
391 cleaning and disinfection products were adapted to the specific requirements of the  
392 clinic. Difficulties were experienced for the installation of sufficient hand hygiene  
393 equipment. Washing stations were not present in all examination rooms after  
394 intervention and construction of more stations was not always feasible. New hand  
395 hygiene disinfection stations were mounted in all participating clinics but were still  
396 lacking in Clinic 2 after intervention.

397

#### 398 *Hand hygiene adherence before and after intervention*

399 In total, 5116 hand hygiene observations were carried out. Of these, 90 observations  
400 were classified as “non-coded”, i.e. none of the five moments for hand hygiene could  
401 be allocated to the observation, leaving 5026 observations to be included in statistical  
402 analysis. Overall mean hand hygiene compliance [95% confidence interval] was 20.9%  
403 [19.2–22.8%] before intervention and 42.5% [40.4–44.7%] one month and 38.7%  
404 [35.7–41.7%] five months after intervention. Hand hygiene improved in all clinics after  
405 training, also at five months (Figure 2). Hand hygiene was lowest in Clinic 2 at baseline  
406 (14.9% [12.1–18.2%]) and after intervention (30.5% [26.6–34.6%]).

407 When looking at the professional groups in the four clinics, an increase in mean hand  
408 hygiene compliance was achieved in veterinarians in all clinics after intervention and  
409 this improvement was still present five months after intervention (Figure 3). In contrast,  
410 the nurses showed an increase in mean hand hygiene compliance only in Clinics 1 and  
411 4.

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

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

416 Hand hygiene was lowest in the pre-operating preparation area at baseline (Figure 5).

417 After intervention, hand hygiene compliance increased in the pre-operating preparation  
418 area and was the best performing area in Clinics 2 and 4.

419

#### 420 *Staff feedback on IPC intervention*

421 The summarized responses of the questionnaires sent to the staff of Clinics 1–4 can  
422 be found in Supplementary Table S2. A total of 37 filled questionnaires were available  
423 for analysis. The personnel judged the general hygiene practices in their clinic (median,  
424 range) as a 5 (0–9) before and as a 7 (2–10) after intervention. The hand hygiene  
425 compliance was rated (median, range) a 5 (2–9) before and a 7 (3–10) after  
426 intervention. Quality of cleaning and disinfection was judged median (range) 6 (0–9)  
427 before and 7 (4–10) after intervention. The practicability of the hand hygiene practices,  
428 the implemented cleaning and disinfection protocols and the isolation measures were  
429 all rated (median, range) a 7 (1–10; 1–10 and 2–10, respectively). The quality of the  
430 lectures was rated (median, range) an 8 (0–10). Overall, 70% of the respondents  
431 expressed the wish to receive additional education on hand hygiene and other hygiene  
432 practices. Additionally, 51% also requested further education on prudent antimicrobial  
433 use and zoonoses, 49% on ARM.

434

#### 435 **Discussion**

436 This study documents generally low IPC practices in four companion animal clinics in  
437 Switzerland before the introduction of comprehensive IPC guidelines. At baseline, the  
438 clinics reached 48–60% of the maximum IPC score in the audit, which is in agreement  
439 with a previous study from Switzerland, where three companion animal clinics reached

440 28–52% of the maximum IPC score [19]. As in the previous study [19], a CPE  
441 contamination was detected in one companion animal clinic in this study (Clinic 2): a  
442 total of 15.5% of the environmental swabs tested positive for ARM and 11.5% for CPE  
443 at baseline evaluation in this clinic. The dissemination of OXA-48 CPE in this clinic is  
444 particularly worrisome as CPE is considered an “urgent” public health threat since a  
445 case fatality rate of up to half of the cases has been documented in human infections  
446 [51,52]. The finding that two out of nine companion animal clinics in Switzerland  
447 examined in our two studies showed massive environmental contamination with ESBL-  
448 E, CPE and Meticillin-resistant *S. pseudintermedius* is alarming [10,19]. It highlights  
449 the rapid emergence of CPE and other ARM of public health concern in companion  
450 animal medicine [2]. In our previous studies, we also documented a high-rate of  
451 acquisition of CPE by patients during hospitalization in the clinic [2] and the  
452 colonization of employees with epidemic clones of CPE closely related to  
453 environmental and patient-derived isolates [23]. This underlines the lack of efficient  
454 IPC practices to break transmission chains between patients, staff and the clinical  
455 environment in these settings [2,19,23]. There is thus an urgent need to foster IPC and  
456 to investigate the effect of IPC interventions on IPC standards, environmental  
457 contamination with ARM and hand hygiene in companion animal clinics.

458 After a multimodal IPC intervention, the IPC scores in all four clinics improved and the  
459 clinics achieved similarly high scores (81–86% of the maximum score) one month after  
460 intervention. During the intervention, a special focus was set on written surface  
461 disinfection protocols, written isolation protocols, on the adaptation of the cleaning and  
462 disinfection products in the clinic and the addition of hand hygiene equipment in the  
463 patient areas. With these measures, ARM contamination in Clinics 1, 3 and 4 was  
464 undetectable after intervention. Furthermore, an increase in cleaning frequency, as  
465 evaluated by fluorescent tagging, was evident in all clinics. In contrast to Clinics 1, 3

466 and 4, the intervention was not successful in Clinic 2 in reducing or eliminating the  
467 extensive ARM contamination in the clinical environment. Our IPC scoring system did  
468 not really capture these failures in Clinic 2 at baseline and after intervention. The  
469 continuous presence of *bla*<sub>OXA-48</sub> might point towards a common source of  
470 contamination in this clinic. A temporary patient stop to perform an extensive cleaning  
471 and disinfection of all surfaces and utensils of the clinic prior to IPC intervention might  
472 have been necessary to combat the outbreak in this institution. The IPC intervention  
473 performed in this study might not have been sufficient to address an outbreak situation.  
474 The IPC score used in this study was based on an audit protocol published as part of  
475 the American Animal Hospital Association (AAHA) Infection Control, Prevention, and  
476 Biosecurity Guidelines [21]. The protocol captures 15 areas of general IPC and is not  
477 specifically tailored to assess and combat ARM. The protocol might need to be adapted  
478 for future use to identify clinics with potential ARM dissemination. For instance, certain  
479 aspects such as equipment and utensils on critical surfaces, the number of hand  
480 hygiene dispensers, cleaning frequency and hand washing stations might need to be  
481 introduced into future scoring systems. Clinic 2 which showed severe ARM  
482 contamination reached amongst the lowest scores in the areas of general IPC  
483 management, cleaning and disinfection, hand hygiene and isolation measures. Hand  
484 hygiene infrastructure was absent in several animal patient areas in this clinic.  
485 Furthermore, observations during the audit revealed that the clinic was generally less  
486 cleaned-up than the other clinics, and equipment and utensils were present on  
487 surfaces in critical areas such as the pre-operating preparation area, making cleaning  
488 and disinfection more difficult. Staff members also used hip pockets (taille organizers)  
489 to store utensils such as scissors during daily work. Such practice has previously also  
490 been observed in another companion animal clinic with a severe CPE outbreak [19].  
491 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 assess 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

518 compliance of 26% to 47% [31,37]. In this study, hand hygiene compliance increased  
519 from 21% before intervention to 43% one month and 39% five months after  
520 intervention, which documents that a significant and prolonged effect on hand hygiene  
521 can be achieved in veterinary staff by education and training. The decrease in  
522 adherence five months compared to one month after intervention might indicate that  
523 repetitive training of the staff, at least every twelve months [21] might be required to  
524 maintain compliance. It was however interesting that our hand hygiene campaign  
525 improved hand hygiene compliance primarily in veterinarians, whereas the effect was  
526 much less pronounced in veterinary nurses. Hand hygiene adherence in veterinarians  
527 improved in all clinics after intervention, whereas this was only achieved in two clinics  
528 in nurses. This is in contrast to studies in human hospitals which reported that nurses  
529 respond better to hand hygiene training than doctors [36,55,56]. In this study, all staff  
530 members received the same teaching as part of IPC implementation. The results  
531 indicate that the hand hygiene lectures and training need to be better adapted to the  
532 nursing staff and that separate training lessons might be required for these two  
533 professional groups.

534 Hand hygiene was lowest in the pre-operating preparation area before and in the ICU  
535 after intervention. Such areas with a high activity index, i.e. many opportunities for  
536 hand hygiene per hour, are prone to low hand hygiene compliance [57]. These results  
537 go in line with previous studies which document lower compliances in these critical  
538 areas [31,37]. The WHO five moments for hand hygiene guideline had originally been  
539 developed for stationary patient areas in hospitals which allow to clearly identify a  
540 patient area that needs to be protected [34]. In high activity areas such as ICUs or pre-  
541 operating preparation areas, such patient areas are less clearly defined. Furthermore,  
542 the high activity index makes adherence to the 5 moments for hand hygiene more  
543 difficult. However, a good hand hygiene is of particular importance in such high traffic

544 and high risk environments as there is an increased risk for ARM contamination and  
545 transmission [19,58].

546 In agreement with previous studies in veterinary clinics, hand hygiene compliance was  
547 lowest before clean/ aseptic procedures and high after patient contact and after body  
548 fluid exposure risk [26,28,37], indicating that hand hygiene is often performed mainly  
549 for self-protection purpose. A similar pattern is also observed in human medicine where  
550 “before clean/aseptic procedures” is the indication with the lowest compliance and  
551 “after patient contact” and “after body fluid exposure risk” those with the highest hand  
552 hygiene compliance [56,59]. After intervention, “before clean/ aseptic procedures”  
553 remained the indication with the lowest compliance, but hand hygiene “before touching  
554 a patient” became the second-best performing indication. This might indicate that the  
555 indication “before patient contact” is easier to teach and to put into practice than before  
556 clean aseptic procedures. Our results contrast with a study from human medicine that  
557 found no change in the hand hygiene indication pattern after training. A study in  
558 veterinary medicine however showed that the presence of posters had a significant  
559 effect on hand hygiene “before patient contact” and “before clean/aseptic procedures”  
560 [28].

561 The present study also has its limitations. For one, the IPC scoring system, although  
562 carried out by two people, might be subjective to interpretation. Additionally, the  
563 Hawthorne effect may have caused an overestimation of the hand hygiene results as  
564 direct observation may lead to a higher compliance [60,61]. Particularly after IPC  
565 intervention, this effect might have been more pronounced. To address this bias, a  
566 large number of observations was carried out over prolonged periods of time and as  
567 discreet as possible, because studies have shown that the Hawthorne effect is  
568 transient and decreases over time and with an increasing number of observations [38].  
569 Furthermore, only four clinics were included in the present study. Thus, the results

570 might not be generally applicable to other clinics. In addition, the microbiological  
571 analyses at baseline were interrupted due to the COVID-19 pandemic, and thus these  
572 microbiological samples were collected relatively long before the IPC intervention  
573 started. However, environmental contamination with ARM was low in Clinics 1, 3 and  
574 4 before and after the intervention, and no decrease was observed in Clinic 2 which  
575 showed extensive ARM contamination. All other data (IPC audit scoring, hand hygiene  
576 evaluation, fluorescent tagging) were collected or re-confirmed directly before the  
577 development and implementation of the IPC guidelines when most COVID-19  
578 measures had already been lifted. Furthermore, given the very low environmental  
579 contamination with ARM at baseline in three of the clinics, the question to which extent  
580 the IPC intervention impacted the clinics at a microbiological cannot be fully answered  
581 by our study. The study focused on selected ARM, so it cannot be excluded that an  
582 effect on other pathogens or on hospital-acquired infections was present but missed  
583 due to the study set-up. Lastly, the final follow-up was conducted five months after  
584 intervention, and it remains unclear whether the positive effect of IPC implementation  
585 continued beyond this time.

586

## 587 **Conclusion**

588 The present study identified low IPC practices in companion animal clinics in  
589 Switzerland and extensive environmental contamination with ARM of public health  
590 concern in one of the clinics. The conducted IPC intervention was successful in  
591 improving general IPC practices and hand hygiene compliance in all clinics.  
592 Environmental contamination remained however high in the clinic with massive CPE  
593 spread. This may indicate that clinics with extensive contamination may require more  
594 targeted interventions to improve IPC and omit ARM spread. The hand hygiene  
595 campaign improved hand hygiene in the veterinary staff 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.

622

623

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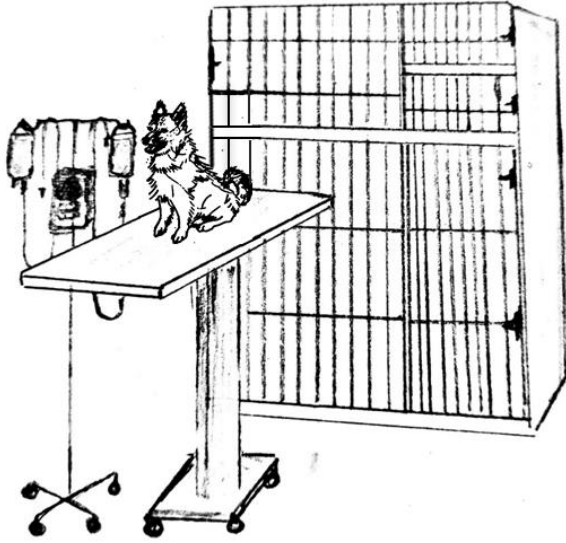
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852 **Tables and Figures**

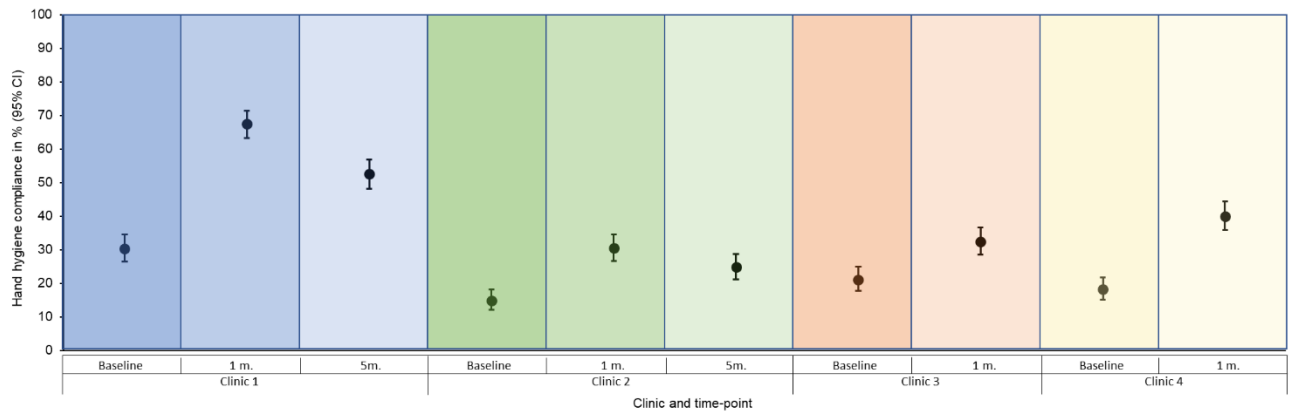
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855 Figure 1. The patient and the patient zone comprising all areas that could potentially  
856 come into contact with the patient, such as the table, the ward, the infusion pump and  
857 IV lines.

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860 Figure 2. Mean hand hygiene compliance (%) with 95% confidence intervals in Clinics

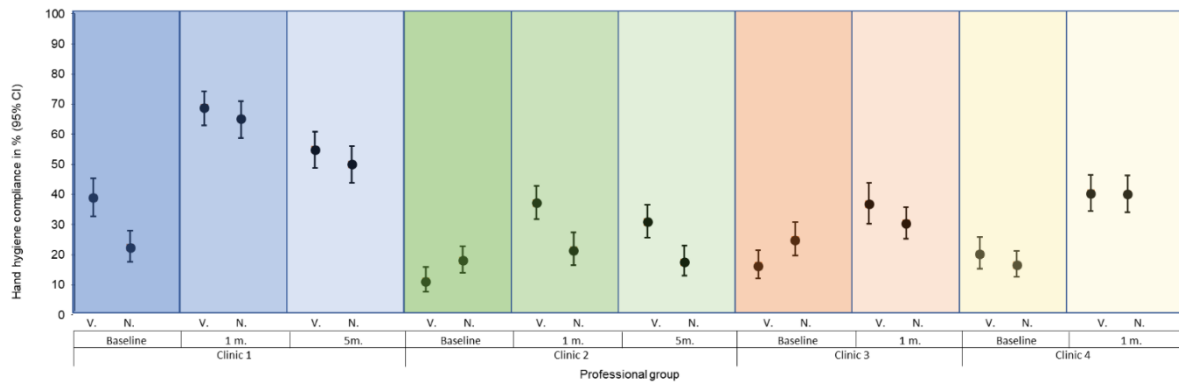
861 1–4 at baseline and 1 month (all clinics) and 5 months (two clinics) after intervention.

862 Abbreviations: 1m., one month follow-up; 5m., five-month follow-up

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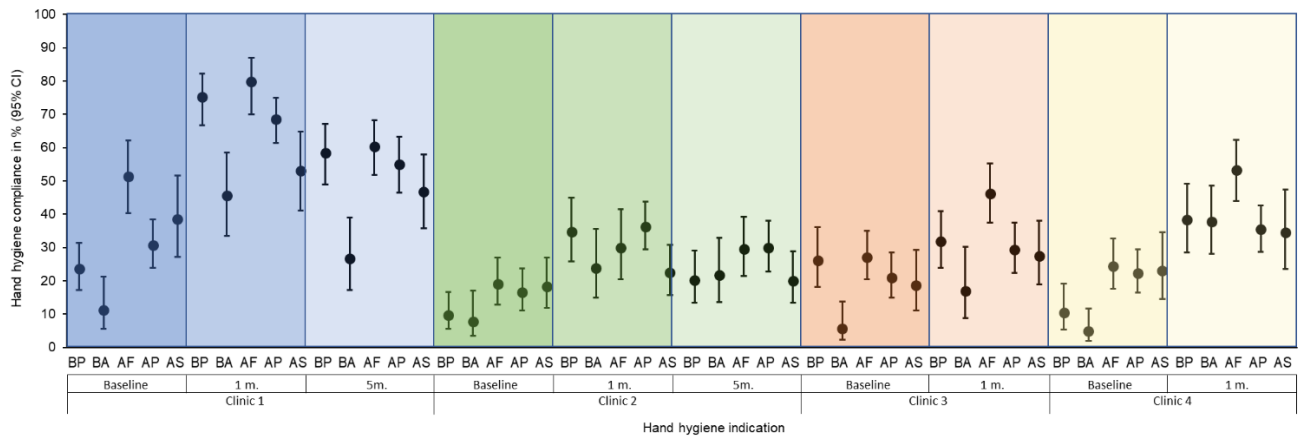
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867 Figure 3. Mean hand hygiene compliance (%) with 95% confidence intervals in  
 868 veterinarians and nurses in Clinics 1–4 at baseline and 1 month (all clinics) and 5  
 869 months (two clinics) after intervention.

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

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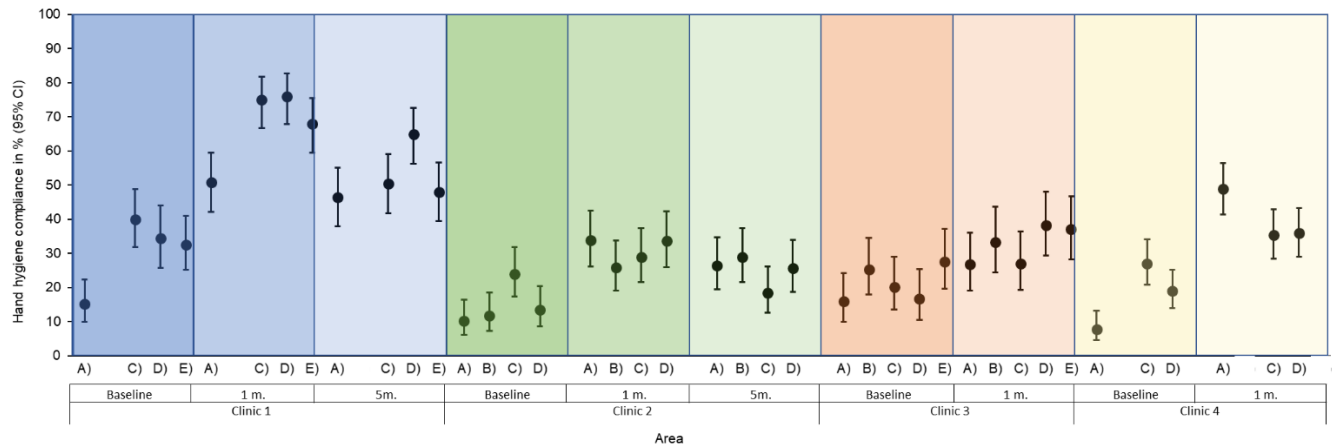
875 Figure 4. Mean hand hygiene compliance (%) with 95% confidence intervals according  
 876 to hand hygiene indication in Clinics 1–4 at baseline and 1 month (all clinics) and 5  
 877 months (two clinics) after intervention.

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

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

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

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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	0.5%	0%	0%	15.5%	7.5%	16.0%	1.0%	0%	1.5%	0%
environment	[0.0–2.8]			[11.1–21.2]	[4.6–12.0]	[10.1–24.4]	[0.2–3.6]		[0.4–4.3]	
al swabs (%)	n=200	n=200	n=100	n=200	n=200	n=100	n=200	n=200	n=200	n=200

[95%]) and

number of

samples)

Type of ARM	ESBL-E			CPE, ESBL-E, MRS	CPE, ESBL-E	CPE, ESBL-E, MRS	ESBL-E, MRS		ESBL-E	
in										
environment										
al swab										

Fluorescent	8.9%	52.2%	33.3%	16.7%	30.0%	32.2%	18.9%	31.1%	16.7%	27.8%
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tags cleaned

in % of total

number of

tags (90)

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

\* Meticillin-resistant *Staphylococcus aureus* in all positive hand swabs

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

Audit area (total score)	Clinic 1		Clinic 2		Clinic 3		Clinic 4	
	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