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A Systematic Review of The Effectiveness of Cohorting To Reduce Transmission of Healthcare-associated *C. difficile* and Multi-Drug Resistant Organisms

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Abstract

BACKGROUND: Cohorting of patients and staff is a control strategy often used to prevent the spread of infection in healthcare institutions. However, a comprehensive evaluation of cohorting as a prevention approach is lacking.

METHODS: We performed a systematic review of studies that used cohorting as part of an infection control strategy to reduce hospital-acquired infections. We included studies published between 1966 to November 30, 2019 in adult populations hospitalized in acute-care hospitals.

RESULTS: 87 studies met inclusion criteria. Studies were quasi-experimental “before and after” (n=35), retrospective (n= 49), or prospective (n=3). Case-control analysis was performed in 7 studies. Cohorting was performed with other infection control strategies in the setting of Methicillin Resistant *Staphylococcus Aureus* (MRSA) (n=22) *Clostridioides difficile* infection (CDI) (n=6), Vancomycin Resistant *Enterococcus* (VRE) (n=17), carbapenem resistant *Enterobacteriaceae* infections (n=22), *A. baumannii* (15), or other gram negative infections (n=5). Cohorting was performed either simultaneously (56/87, 64.4%) or in phases (31/87, 35.6%) to help contain transmission. In 60 studies, both patients and staff were cohorted. Majority of studies (77/87, 88.5%) showed a decline in infection or colonization rates after a multi-faceted approach

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that included cohorting as part of the intervention. Hand hygiene compliance improved in about half of studies (8/15) during intervention.

CONCLUSION: Cohorting of staff, or patients, or both is a frequently used and reasonable component of an enhanced infection control strategy. However, determining the effectiveness of cohorting as a strategy to reduce transmission of MDRO and *C. difficile* infections is difficult to assess particularly in endemic situations.

Summary:

Cohorting is frequently used as a component of an enhanced infection control strategy. Determining the effectiveness of cohorting as a strategy to reduce transmission of MDRO and *C.difficile* infections is difficult to assess.

Keywords

Cohorting; Infection Control; Multi-drug resistant organism (MDRO)

INTRODUCTION

Multidrug resistant organisms (MDROs) are increasingly common in healthcare settings, and are associated with considerable morbidity, mortality and costs. This growing crisis in antimicrobial resistance has prompted increased attention on infection control (IC) efforts to reduce transmission in healthcare settings. IC measures are typically implemented as bundles of enhanced surveillance, education, hand hygiene, personal protective equipment and environmental controls (such as single patient rooms and room disinfection). One such method of reducing transmission is cohorting, often employed when routine measures fail to control an outbreak.

Cohorting is the practice of grouping together patients who are colonized or infected with the same organism to confine their care to one area and prevent contact with other susceptible patients.¹ It has been used extensively for managing outbreaks of multi drug-resistant organisms (MDRO) including Methicillin Resistant *Staphylococcus aureus* (MRSA)^{2,3}, Vancomycin Resistant Enterococcus (VRE)^{4,5}, *Clostridioides difficile* infection (CDI)⁶, Extended Spectrum Beta Lactamase (ESBL)⁷ producing organisms, and Carbapenem Resistant Enterobacteriaceae (CRE).⁸⁻¹⁰ It has also been used to contain viral outbreaks such as respiratory syncytial virus among children^{11,12} and Severe Acute Respiratory Syndrome (SARS).¹³ Staff cohorting, or assigning healthcare personnel to care only for patients infected or colonized with a single target pathogen, limits further transmission of the target pathogen to uninfected patients.^{14,15} However, cohorting, particularly of staff, is usually costly and difficult to maintain due to staff shortages in hospitals.¹⁶

A comprehensive evaluation of patient and staff cohorting as a prevention approach is lacking. We performed a systematic review to determine its effectiveness as an infection control strategy.

METHODS

This systematic review is reported according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines.¹⁷

Study Criteria

We included studies published between 1966 to November 30, 2019 in adult populations hospitalized in acute-care hospitals. We only included studies that reported use of patient and/or staff cohorting as part of an infection control intervention AND which included outcome data, reported either as absolute number of colonization/infections or colonization/infection rates. Studies involving the pediatric population, or performed in long-term acute care facilities (e.g. LTAC or nursing homes) were excluded.

Search Methods

With the help of a professional librarian we searched MEDLINE, EMBASE (OvidSP), from inception through November 30, 2019. We used medical subject headings (MeSH) and terms for cohorting AND multi drug-resistant organisms (e.g. VRE, MRSA, ESBL, CRE) or *C. difficile*. Reference lists of included studies and studies cited in previous reviews were screened. Furthermore, 2 independent reviewers (CLA, NS) performed abstract screenings and full-text reviews. Reviewers were not blinded for author, institution, or journal names. Language was restricted to English.

Data Abstraction and Management

The following data were abstracted: study design, country, study year(s), type of hospital/setting, type of infection, description of infection control interventions and outcomes. For purposes of this study, cohorting was defined as a grouping together or segregation of patients colonized or infected with the same organism in one area of a unit (e.g. geographic) or in a specially built or separate unit, entirely. Cohorting could involve patients, or both patients and staff. Data was extracted by CLA, and discrepancies were resolved by consensus between the two authors (CLA and NS).

Quality and Bias Assessment

We used the Downs and Black Checklist for Measuring Quality¹⁸, which has 27 items for evaluating the following parameters: reporting, internal and external validity, confounding, and power. The maximum score is 28. The risk of bias was independently assessed by two reviewers (AB, CLA) without blinding to the journal or study authorship. Discrepancies were resolved by discussion or involvement of a third review author (NS) if required.

Outcomes

The primary outcome was rate of colonization or hospital-acquired infection (HAI). Acceptable definitions were incidence rates or incidence density (e.g. # colonization or HAI/1000 patient days), absolute number of colonizations/infections, or risk ratio. Secondary outcomes included compliance with infection control intervention/s and adverse events.

Data Synthesis

We considered a formal meta-analysis inappropriate because of heterogeneity in outcome measures and patient populations.

RESULTS:

We searched PUBMED and EMBASE databases, yielding a total of 2,356 articles. Title and abstracts were screened, and 159 articles were retrieved for review. Screening of references added 19 additional papers. After careful review, 87 studies met inclusion criteria^{3–8,10,19–98} (Figure 1). The full search strategy is attached in supplementary Appendix 1.

Characteristics of Included Studies

Of the 87 studies, there were no randomized controlled trials. Majority were retrospective (n= 49) or quasi-experimental “before and after” (n=35)^{3,4,10,20,21,23,24,26,28,29,31–34,38,40,42,43,46,51,52,55,57–59,62,68,76,77,80,83,85,86,89,97} studies. The remaining 3 were prospective studies^{8,25,41}. Case-control analysis was done in 7 studies^{22,35,53,72,82,93,98}. Most were performed in tertiary level (n=75), followed by secondary (n=7),^{33,35,44,47,80,88,97} primary (n=2)^{4,58} and specialty hospitals (n=3) [e.g. military hospital, research institute]^{57,73,74}. There were 29 studies carried out in the ICU^{7,8,19–21,26,28,30,43,44,48,50,52,55,57–60,62,66,67,70,71,74,77,88–91}, 19 studies in wards^{4,5,29,34,41,42,64,68,72,82,85,87}, or specialty areas^{22,24,49,54,65,83,84}, and 39 involved multiple units or were hospital-wide^{3,6,10,23,25,27,31–33,35–40,45–47,51,53,56,61,63,69,73,75,76,78–81,86,92–98}. Majority of studies (65/87, 74.7%) were performed in the setting of an outbreak while the rest were not^{4,6,10,20,21,23,28,32,38,40,41,43,44,54,57,62,68,70,73,75–81,83,86,89,93–95}. Most focused on specific pathogens, including MRSA (n=22)^{3,22,24,26,28,32–34,37–41,44,50,54,62,64,65,77,81,83}, VRE (n=17)^{4,5,25,30,48,55,61,63,68–70,79,82,87,92,94,96}, *Clostridioides difficile* (n=6)^{6,29,35,47,76,85}, Extended spectrum beta-lactamase producing organisms (ESBL) or Carbapenem resistant enterobacteriaceae (CRE) [n=22]^{10,27,31,36,46,49,51,52,58,59,71–73,75,78,80,84,88,90,93,97,98}, and multi drug resistant -*Acinetobacter baumannii* (MDR-Abau) [n=15]^{7,19–21,42,43,45,53,56,60,66,67,74,91,95}. A few studies (n=5)^{8,23,57,89,99} looked at multiple MDR organisms (MDRO). Summary of study findings is in Table 1 and characteristics of included studies are in Table 2.

Study Quality and Bias Assessment—Our average study score was 14.9 (range 12–22) points. Studies scored highly on external validity but poorly on power. (Supplementary Appendix 2)

Description of Cohorting—Cohorting was performed in the setting of other infection control interventions, either maintained throughout the duration of the interventions (56/87, 64.4 %), or limited to certain phases (31/87, 35.6%)^{3,5,8,19,20,26,28,31,32,36–39,46,49,50,53–56,63,64,67,69,70,77,78,85,87,89,93}. In majority of studies, cohorting was described as physical separation of patients within a section of a unit (55/87, 63%). In about a third, a dedicated area or ward was created for patients (34/87, 39%)^{3,4,6,19,23,29,32,33,35–38,41,43–45,47,59,61,69,76,78–82,86,92,93,95–99} w/

two studies doing both^{37,38}. In majority of studies, both patients and staff were cohorted (60/87, 68.9%) while the rest (27/87, 31.0%) cohorted patients alone^{6,10,20,21,24,26,30,32,35,37,38,40,41,43,44,51,54,62,65,70,77,83–85,89,92,95}. Potential adverse effects from cohorting were discussed in 12 studies^{8,19,25,28,33,34,44,59,61,78,86,89}. These adverse effects included increased anxiety or feeling of isolation^{28,34}, increased workload for the healthcare team^{61,78}, higher cost^{19,33}, disruption of patient care^{59,61}, potentially less time spent with the healthcare team²⁸, increase in other MDRO²⁵, or no adverse effects⁸. In one study⁸⁶ the authors used surrogate markers such as falls and pressure ulcers to evaluate adverse events from contact precautions, and none was observed. In contrast, in two studies^{44,89}, cohorting led to increased time spent with patients⁸⁹ and decreased cost⁴⁴. A description of cohorting and the other interventions used is summarized in Table 3 and Supplementary Appendix 3, respectively.

Effect of Cohorting: Outcome

C. difficile infection (CDI)—Six studies evaluated the effect of cohorting on CDI^{6,29,36,47,76,85}. In all but one study⁸⁵, patients were cohorted in separate units from patients without CDI. Two studies were performed in hospitals where *C. difficile* was endemic^{6,76}. CDI rates or numbers decreased in 4/6 studies^{29,35,76,85}. In one study⁶, there was no change in number of CDI recurrences despite cohorting, while in the other⁴⁷, cohorted patients had a higher risk of CDI recurrence, with an OR of 3.94 (1.23–12.65; *P* = 0.021) [Table 4].

Methicillin Resistant Staphylococcus Aureus (MRSA)—Twenty-two studies included the use of cohorting to control MRSA infection^{3,22,24,26,28,32–34,37–41,44,50,54,62,64,65,77,81,83}. MRSA was endemic in 10 studies^{28,32,38,40,41,44,54,62,77,83}. Cohorting was used as the major intervention in only 3 studies^{41,44,81}; all other studies used multiple other interventions. Majority of studies showed a decrease in MRSA colonization/ infection after initiation of a multi-faceted strategy, although rates remained unchanged in 3^{26,28,44} and increased in 1³⁸. In 3 studies^{22,33,34} rates of MRSA infection specifically declined after initiation of cohorting. 2 studies looked at compliance w/ hand hygiene^{40,62} or use of gloves, which did not change during the intervention period. A summary of outcomes is in Table 4.

Vancomycin Resistant Enterococcus (VRE)—Seventeen studies included cohorting as part of a strategy to help control VRE infection^{4,5,25,30,48,55,61,63,68–70,79,82,87,92,94,96}. All but 3 studies^{4,68,70} were performed in the setting of a VRE outbreak. There was a significant decline in VRE numbers or incidence after enhanced infection control measures with the exception of 1 study⁴. In that study⁴, there was a noted decrease from 0.28 /100 admissions vs. 0.09/100 admissions specifically during the cohort ward intervention [RR 0.32 (CI=95, 0.69–15.85) *P*=0.2], but this was not statistically significant. However, in this study, staff compliance w/ infection control measures improved during the cohort intervention from 5/23 (21%) to 36/41 (88%) *p*<0.001. In another study, only partial control of the outbreak was achieved despite multiple interventions⁹⁴. Time to outbreak control was varied - as short as 2 months in one⁸², to as long as 3 years in another⁶³. Hand hygiene compliance, which was reported in 3 studies^{4,63,70} all improved during the intervention phase.

Carbapenem Resistant Enterobacteriaceae (CRE) /Extended Spectrum beta-lactamase (ESBL) producing organisms—Twenty two studies evaluated the use of cohorting as part of an intervention to control drug-resistant Enterobacteriaceae, all in the setting of an outbreak^{9,10,27,31,36,46,49,51,52,58,59,71–73,75,78,84,88,90,93,97,98}. Most involved CRE, with the exception of 2 studies with ESBL-producing *Klebsiella* sp.^{58,59}. In both, rates of ESBL decreased; from 11.57/1000 PD to 0.08/1000 PD [RR 0.11] and from 8.6/1000 PD to 0, after intervention, respectively.

In all studies, there was control of the outbreak after use of multiple infection control interventions. In the study by Nouvenne⁹³, there was a statistically significant decrease in the incidence of new cases from 18–23 cases/month to 8 cases/month (range 3–13) specifically after the cohorting intervention ($p=0.04$). The length of time until outbreak control varied widely, from as short as 1 month²⁷ to as long as 1 year^{49,73,84}. Among the four studies^{31,51,73,98} that reported hand hygiene compliance, there was an increase in compliance rates in 2^{51,73}; the other 2 did not provide baseline data.

A. baumannii—Fifteen studies looked at the use of enhanced infection control measures including cohorting in the setting of MDRO-*A. baumannii* infection^{7,19–21,42,43,45,53,56,60,66,67,74,91,95}. In 4 studies^{20,21,43,95}, *A. baumannii* was endemic in the institution. In all instances there was control of the MDR-*A. baumannii*. However, time to outbreak control took 1–2 months^{42,60,67} to over a year in others^{7,45,56}. In two studies that observed more than one outbreak^{74,91} control was shorter the second time around from 6 vs.3 months⁷⁴ and 152 vs. 37 days⁹¹, respectively. In 4 studies^{20,21,66,95} that reported hand hygiene compliance rates, improvement was only noted in one⁹⁵.

Other MDROs—Five studies^{8,23,57,86,89} evaluated MDRO-related infections. Most studies were done in institutions where the MDRO was endemic, except for one⁸. In this study, the absolute number of multiple non-clonal gram-negative MDRO's decreased from 6 to 0 post-intervention⁸. There was also a decrease in MDRO rates in 2 other studies^{57,86}. The one study evaluated Ventilator associated pneumonia (VAP)- ESKAPE pathogen rates in a military hospital,⁵⁷ and reported a decrease in VAP rates from 60.6 to 11.1/1000 patient days ($p = 0.029$). In the other study,⁸⁶ there was a significant decrease in the trend of MDRO after an isolation unit was created (trend change from 0.65 to 1.04; $P = .01$). Most of the observed reduction was related to the reduction of infections due to VRE (trend change from 0.69 to 1.04; $P = .01$) and carbapenem-resistant *P. aeruginosa* (trend change from 1.35 to 1.45; $P = .01$). There was no significant change for ESBL-producing organisms, MRSA, and carbapenem-resistant *A. baumannii*. In the remaining two studies that also used cohorting as the main intervention^{23,89}, there was no change in colonization or incidence rates despite it. In the study by Arruda²³, in particular, there was no immediate effect of cohorting on the incidence density of MDR bacteria acquisition ($\beta_2: -1.32$; 95% CI: 3.81 to 1.16; $P = .28$). In the sole study that reported hand hygiene compliance, there was a significant increase from 54 to 66% pre and post-intervention⁸⁹.

DISCUSSION

In this systematic review, we found that cohorting was used in conjunction with other infection control measures, generally in the setting of an outbreak. While the majority of the studies in this review (77/87, 88.5%) showed a decline in colonization or infection rates after institution of a multi-faceted approach that included cohorting as part of the intervention, it is not possible to determine the independent effect of cohorting in these studies. Once pathogens (MRSA or gram negative MDROs) are endemic, control is challenging, even with cohorting.

Studies were heterogeneous and analysis of bias and risk assessment fell in the fair category (mean 14.9). Notably, the process of cohorting varied across all studies -- cohorting involved creation of a dedicated ward or separate unit, or just sectioning off a part of the unit; cohorting was performed throughout the duration of the outbreak, or maintained only in certain phases; and finally, cohorting either involved patients alone, or both staff and patients. All these differences make it difficult to assess the process of cohorting itself, but the outcomes were consistent across studies regardless of this variation in cohorting practices.

Most studies cohorted both patients and healthcare staff as opposed to patients alone (60 vs. 27). In these studies, staff provided care for only those patients already infected or colonized with the resistant pathogen. Staff did not cross-cover between infected/ colonized and non-colonized patients. Intuitively, cohorting staff to care for infected and colonized patients should have a substantial impact on nosocomial transmission, and keeping infected and colonized patients separate from non-infected and non-colonized patients provides a powerful tool to prevent transmission. Assigning staff to cover only patients who are infected may be a key mechanism for preventing transmission in the healthcare setting¹⁰⁰. Proving this theory is difficult, however, given the concomitant use of other interventions. However, staff cohorting can also be very costly, and can lead to increased burden to the provider and the healthcare system³³, which may explain why in some studies in this review (31 vs. 56 studies), cohorting was done only in discrete phases, and was not continuous. Given the heterogeneity in the studies we were not able to compare the relative benefit of staff versus patient cohorting.

In a few studies that evaluated MRSA^{28,38,39,77} rates of infection remained unchanged or even increased despite the use of cohorting and other concomitant infection control strategies. In these studies, the failure to reduce infection was likely multifactorial and included a rise in numbers of colonized patients on admission, a possible change in strain,³⁹ or because of delayed identification of unknown cases.³⁸ In a systematic review of infection control isolation measures in the management of MRSA which included 46 studies,¹⁰¹ four studies (one of which is included here³⁷) provided strong level of evidence that intensive control measures including patient isolation were effective in controlling MRSA. In the two other studies which are included in this review,^{38,39} isolation wards failed to prevent endemic MRSA.

The risk of recurrent *C. difficile* infection seemed higher with cohorting compared with use of single rooms, at least in 2 studies. The authors attributed this to the possibility that patients admitted to a cohort unit are at greater risk of *C. difficile* reinfection because of persistent exposure to environmental spores. However, there was no molecular typing or molecular analysis of the *C. difficile* strains. This would have helped differentiate between recrudescence infection versus reinfection from another source.

Interestingly, there was reduction of CRE or ESBL-producing Enterobacteriaceae in all 22 studies that used multi-modal interventions during an outbreak setting. This implies that cohorting as an intervention for outbreak control is reasonable as part of enhanced infection control precautions, often in conjunction with stewardship measures. However, the possibility of regression to the mean during the setting of an outbreak is often a confounding factor and must also be considered. Given the heterogeneity in organisms that comprise CRE, further study is also needed to determine if there is a differential risk of transmission among the CRE, in the context of the close proximity that comes with cohorting of patients.

Our systematic review has several limitations and strengths. The studies were too heterogeneous and did not allow for a formal meta-analysis. Given the multi-faceted approach to outbreak control, we also could not isolate the role or quantify the importance of cohorting in such a strategy. Despite the limitations, we used a comprehensive search strategy, data extraction and documentation of threats to validity to provide an evaluation of the shortcomings of existing research. Although we cannot determine the effect of cohorting as a separate strategy for infection control, the evidence thus far suggests that cohorting may be a reasonable strategy to add as part of a multi-modal approach in the effort to curtail MDRO outbreaks. Whether it is an effective strategy in endemic situations remains unknown and future studies should examine the effect of cohorting particularly for institutions where MDRO or *C. difficile* are endemic.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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Figure 1:
Flow Diagram

Table 1:

Summary of Study Findings

Characteristic	N	%
Type of Pathogen	87	100
<i>Clostridioides difficile</i>	6	6.90
MRSA	22	25.29
CRE/ESBL	22	25.29
<i>A. baumannii</i>	15	17.24
VRE	17	19.54
Other (e.g multiple gram negative organisms)	5	5.75
Setting		
Outbreak/Epidemic	65	74.71
Non-outbreak/Endemic	22	25.29
Infection control intervention		
Mainly cohorting	10	11.49
Multi-modal	77	88.51
Cohorting Style		
Patient only	27	31.0
Both patient and staff	60	68.9
Type of Cohort Area [^]		
Separate ward or unit	35	40.23
Grouping or geographic	54	62.07
Primary Outcome [*]		
Decrease (in number or rate)	77	88.5
Increase	2	2.30
No change	8	9.20

MRSA - Methicillin Resistant Staphylococcus Aureus; CRE- Carbapenem Resistant Enterobacteriaceae, ESBL – Extended Spectrum Beta-lactamase; VRE- Vancomycin Resistant Enterococcus

[^] Total not 87, as 2 studies did both

^{*} Colonization or infection

Table 2:

Summary of Included Studies

AUTHOR, YR ^(ref)	Country	Study Design, duration, setting, [beds]	Outbreak(N) Endemic [organism]	Infection control intervention
<i>C. difficile</i>				
Struelens, 1991 ⁸⁵	Belgium	QE, 8/1988 – 6/1990 Tertiary [840], surgical and medical units	Ob Nosocomial <i>C. difficile</i> disease (NCDD)	Multi-modal
Cherifi, 2006 ²⁹	Belgium	QE, 3/2003–4/2003 Tertiary [758], Geriatric ward	Ob	Multi-modal
Debast, 2009 ³⁵	Neth	R, w/ case control 3/2005–2/2005 secondary, [341] hospital wide	Ob	Multi-modal
Price, 2010 ⁷⁶	UK	QE, 1/2008 to 3/2009, Tertiary [820], hospital wide	En	Cohort ward and ASP only
Islam 2013 ⁴⁷	UK	R, 10/ 2008–6/2011 Secondary [800], Hospital wide	Ob	Multi-modal
Garcia-Lecona 2018 ⁶	Mexico	R, 1/2014–12/2016 Tertiary [500], Hospital wide	En	Cohorting only
<i>MRSA</i>				
Selkon, 1980 ⁸¹	UK	R, 1967–1978 Tertiary, Hospital Wide	Ob	Cohorting and screening only
Arnow, 1982 ²²	US	R with case-control, 2/1975/1975, Tertiary, Burn unit	Ob	Multi-modal
Duckworth, 1988 ³⁷	UK	R, 1982–1985 (5 phases) Tertiary, SC Hospital wide	Ob	Multi-modal
Murray-leisure, 1990 ³	US	QE,10/1987–8/1989 (2 phases) Tertiary [884], Hospital wide	Ob	Multi-modal
Cohen, 1991 ³²	US	QE, 7/1983–6/1990 (3 phases) Tertiary [500], Hospital wide	En	Multi-modal
Faoagali, 1992 ³⁸	Aus	R, 1979–1989 Tertiary [1200], Hospital wide	En	Multi-modal
Cox, 1995 ³³	UK	QE, 4/1991–12/1992, Secondary, Hospital wide	Ob	Multi-modal
Mayall, 1996 ⁶⁴	Aus	R, 12/1992–6/1994, Tertiary [500], thoracic ward	Ob	Multi-modal
Meier, 1996 ⁶⁵	US	R, 3/1993–6/1993 Tertiary [900], Burn unit	Ob	Multi-modal
Farrington, 1998 ³⁹	UK	QE, 1985–1997, Tertiary Hospital wide	Ob	Multi-modal
Fitzpatrick, 2000 ⁴¹	Ireland	Prospective, tertiary referral teaching hospital [486], rehabilitation ward	En (88)	Cohorting only
Cepeda, 2005 ²⁸	UK	PQE; 6/2000–6/2001: Tertiary, MC, ICU	En	Multi-modal
Curran, 2006 ³⁴	UK	QE, 1/2002–4/2004 Tertiary,Vascular surgery ward	Ob	Multi modal
Singh, 2006 ⁸³	US	R, QE; 1996–1999 pre intervention; 2000–2004 postintervention, Tertiary; Transplant unit	En	Multi-modal
Raineri, 2007 ⁷⁷	Italy	QE, 1996–2005 1996–1997 (p1) 1998–2002 (p2) 2003–2005 (p3) Tertiary, ICU	En	Multi-modal
Gilroy 2009 ⁴⁴	US	R, 9/2000–5/2008 Secondary [506], ICU (Dedicated unit)	En	Cohorting only

AUTHOR, YR ^(ref)	Country	Study Design, duration, setting, [beds]	Outbreak(N) Endemic [organism]	Infection control intervention
Khan, 2009 ⁵⁰	Canada	R, 7/2000–9/2000 Tertiary, ICU	Ob	Multi-modal
Batra, 2010 ²⁶	UK	R, QE, 1/1/2002 to 4/ 20/06, Tertiary [840] ICU	Ob/En	Multi-modal
Kusachi, 2011 ⁵⁴	Japan	R, 9/1987 to 8/2007, Tertiary, digestive surgeries	En	Multi-modal
Barbut, 2013 ²⁴	FRA	QE, 12/2006–8/2008 (pre); 9/2008–12/2009 (intervention) Tertiary Burn unit	Ob	Multi-modal
Fisher, 2013 ⁴⁰	Singapore	PQE, Tertiary hospital [995], hospital wide	En	Multi-modal
Marshall, 2013 ⁶²	Aus	PQE, university-affiliated tertiary [350], ICU	En	Multi-modal
VRE				
Karanfil, 1992 ⁴⁸	US	R, 3/2000–6/2000 Tertiary [376], cardio thoracic ICU	Ob (6)	Multi-modal
Lai, 1998 ⁵⁵	US	QE, 5/1993–8/1996 Tertiary [347], ICU	Ob (359)	Multi-modal
Jochimsen, 1999 ⁴	US	QE, 3/1995–2/1996 Primary, medical ward	En	Cohorting
Montecalvo, 1999 ⁶⁸	US	PQE, 11/1993–7/1994 (pre) and 7/1994–7/1995 (post), Tertiary [650], SC Oncology ward	En	Multi-modal
Bartley, 2001 ²⁵	Aus	P, 1/1997–12/1999, tertiary hospital[800], ICU/IDS/ Renal ward	Ob (49)	Multi-modal
Ridwan, 2002 ⁹⁴	Neth	R, 6/2000–9/2000, tertiary teaching hospital [1042], hospital wide	Ob (43)	Multi-modal
Sample, 2002 ⁵	US	R, 4/1998–9/1998 Tertiary [1100], Hematology/Oncology ward	Ob (13)	Multi-modal
Timmers, 2002 ⁸⁷	Neth	R, 11/1998 to 12/1999, Tertiary, hematology ward	Ob (24)	Multi-modal
Christiansen, 2004 ⁹⁶	Aus	R, July to Dec 2001, Tertiary, hospital wide	Ob (169)	Multi-modal
Mascini, 2006 ⁶³	Neth	R, 5/2000–1/2003, Tertiary [1042], hospital wide	Ob (89)	Multi-modal
Lucet, 2007 ⁶¹	France	R, 9/2005–10/2005 Tertiary, Multiple units	Ob (37)	Multi-modal
Schmidt-Heiber, 2007 ⁷⁹	Germany	R, 4/2005–12/2005, Tertiary, hematology ward w/ ICU	Ob (33)	Multi-modal
Kunup, 2008 ⁹²	Singapore	R, 3/2005–6/2005, Tertiary [1600], hospital wide	Ob (151)	Multi-modal
Servais, 2009 ⁸²	France	R w/ case control study, 1/2007–3/2007, Tertiary [2000], Nephrology department	Ob (14)	Multi-modal
Morris-Downes, 2010 ⁷⁰	Ireland	R, 2000–2008, Tertiary [800] ICU	En	Multi-modal
Moretti, 2011 ⁶⁹	Brazil	R, 7/2007– 12/2009, Tertiary [400] hospital wide	Ob (66)	Multi-modal
Chotiprasitsakul, 2016 ³⁰	Thailand	R, 6/2013–1/2014 Tertiary, ICU	Ob (26)	Multi-modal
A. baumannii				
Podnos, 2001 ⁷	US	R, 11/1996 to 12/1997 Tertiary, ICU	Ob (52)	Multi-modal

AUTHOR, YR (ref)	Country	Study Design, duration, setting, [beds]	Outbreak(N) Endemic [organism]	Infection control intervention
Longo, 2005 ⁶⁰	Italy	R, 4/2005–5/2005, Tertiary, ICU	Ob (14)	Multi-modal
Apisarnthanarak, 2008 ²⁰	Thailand	R, 1/2005–12/2007, Tertiary [500], ICUs	En	Multi-modal
Kohlenberg 2009 ⁵³	Germany	R w/ case control study, 2/2006 – 11/2006, Tertiary, hospital wide	Ob (32)	Multi-modal
Palmore, 2011 ⁷⁴	US	R, 5/2007–12/2009 (2 outbreaks) Research hospital, ICU	Ob (29 and 22, but 63 total)	Multi-modal
Ayraud-Thevenot 2012 ⁹¹	France	R, 1/2006–5/2006; 1/2009 (2 outbreaks) Tertiary [1500], ICU	Ob (20 and 7)	Multi-modal
Landelle, 2013 ⁵⁶	France	R, 12/2007–6/2009, Tertiary [860], hospital wide	Ob (38)	Multi-modal
Alfandari, 2014 ¹⁹	France	R, 9/2011–6/2012, Tertiary [400], ICU	Ob (20)	Multi-modal
Apisarnthanarak, 2014 ²¹	Thailand	PQE, 5/2010–12/2012, Tertiary [650], ICU	En	Multi-modal
Cho, 2014 ⁹⁵	Korea	R, 7/2007–6/2009 (P1), 7/2009–12/2012, Tertiary [800], hospital-wide	En	Multi-modal
Gray, 2015 ⁴⁵	Canada	R, 3/2012–1/2014, Tertiary [637], multiple units	Ob (29)	Multi-modal
Gavaldà, 2016 ⁴³	Spain	PQE, 1/2011–1/2012 (pre) 2/2012–12/2014 (post) Tertiary [800], ICU	En	Multi-modal
Molter, 2016 ⁶⁷	Germany	R, 12/2011–1/2012, Tertiary, ICU	Ob (10)	Multi-modal
Gagnaire, 2017 ⁴²	France	QE, 10/2012–11/2012, Tertiary [1600], neurosurgery ward	Ob (5)	Multi-modal
Metan, 2019 ⁶⁶	Turkey	R, 1/2016–6/2016, Tertiary, ICU	Ob (10)	Multi-modal
CRE/ESBL				
Ohana 2006 ⁷²	France	R w/ case control, 9/1999–12/2002, Tertiary, Physical medicine and Rehabilitation unit	Ob CRE-KPN	Multi-modal
Laurent 2008 ⁵⁹	Belgium	QE, 1/2005–5/2006 (P1= 8/2005–10/2005; P2= 11/2005–12/2005) Tertiary, ICU	Ob ESBL	Multi-modal
Kochar 2009 ⁵²	US	QE, 1/2004–12/2005 (pre); 1/2006–4/2006 (post intervention) Tertiary, ICU	Ob CRE-KPN Other MDRO	Multi-modal
Langer 2009 ⁵⁸	US	PQE, 4/2007–6/2007 Primary, ICU	Ob ESBL KPN	Multi-modal
Carbonne 2010 ⁷⁷	France	R, 9/2009–10/2009 Tertiary, multiple hospitals	Ob (13) CRE-KPN	Multi-modal
Gregory 2010 ⁹⁸	Puerto Rico	R, case control, 2/2008–2/2009, Tertiary [328], hospital wide	Ob (26) CRE-KPN	Multi-modal
Kassis-Chikhani 2010 ⁴⁹	France	R, 12/2003–10/2004, Tertiary [716], surgery care center	Ob (8) CRE-KPN	Multi-modal
Munoz-price 2010 ⁷¹	US	R, 1/2009–1/2010, Tertiary [1500], Surgical ICU	Ob (10) CRE-KPN	Multi-modal
Agodi 2011 ⁹⁰	Italy	R, 3/2009–5/2009, Tertiary [500], ICU	Ob (16) CRE-KPN	Multi-modal
Ciobotaro 2011 ⁹⁷	Israel	QE, 1/2006–1/2007; 2/2007–6/2010 Secondary, Hospital wide	Ob CRE-KPN	Multi-modal
Cohen 2011 ³¹	Israel	PQE, 2006–2010, in phases Tertiary [775], hospital wide	Ob CRE-KPN	Multi-modal
Schwaber 2011 ⁸⁰	Israel	QE, 1/2005–4/2007 (pre), 4/2007–5/2008 (post) Secondary, multiple hospitals	Ob CRE	Multi-modal

AUTHOR, YR (ref)	Country	Study Design, duration, setting, [beds]	Outbreak(N) Endemic [organism]	Infection control intervention
Palmore 2013 ⁷³	US	R, 8/2013–12/2013, Research center (National institute of health)	Ob CRE-KPN	Multi-modal
Sisirak 2013 ⁸⁴	Bosnia	R, 1/2010–1/2011, Tertiary, Orthopedic center	Ob (78) CRE <i>S. marcescens</i>	Multi-modal
Vergara-lopez 2013 ⁸⁸	Spain	R, 3/2009–11/2011, Secondary [240], ICU	Ob (42) MDR <i>K. oxytoca</i>	Multi-modal
Kim 2014 ⁵¹	Korea	QE, 2008–3/2010 (pre), to 4/2010–2011 (post) Tertiary[900], Hospital wide	Ob CRE	Multi-modal
Nouvenne 2014 ⁹³	Italy	R, cross sectional study w/ case control, 8/2011–5/2012, Tertiary [1218], hospital wide	Ob (133) CRE-KPN	Cohorting
Viale 2014 ¹⁰	Italy	QE, 6/2010–1/2014 Tertiary, [1450] ICU Transplant, HemaOncology units	Ob CRE	Multi-modal
Hussein 2017 ⁴⁶	Italy	RQE, 1/2005–6/2016, secondary and tertiary hospital [830], hospital wide	Ob CRE	Multi-modal
Decraene 2018 ³⁶	UK	R, 2010–2017, Tertiary, hospital wide	Ob CRE- E. coli, KPN	Multi-modal
Pirs 2019 ⁷⁵	Slovenia	R, 10/2014–2/2016, Tertiary [2200], hospital wide	Ob (42) CRE	Multi-modal
Reeme 2019 ⁷⁸	US	R, 7/2016–4/2017, Tertiary [566], Transplant ICU/step down/Rehab unit	Ob (8) CRE	Multi-modal
Other MDROs				
Landrum 2008 ³⁷	US	PQE 5/2006–8/2006 Military hospital, ICU	En (ESKAPE)	Multi-modal
Rosenberger, 2011 ⁸	US	P, 8/2009–11/2009 Tertiary, Surgical trauma burn ICU	Ob (multiple GN- MDRO)	Multi-modal
Stumpfs, 2013 ⁸⁶	Brazil	QE, 3/2010–2/2011 (pre), 3/2011–2/2012 (post) Tertiary [795], Hospital wide	En (multiple GNMDRO, MRSA)	Cohorting
Wongchaoren, 2013 ⁸⁹	Thailand	PQE, 9/2012– 11/2012, Tertiary, ICU	En ESBL, A. baumannii, P. aeruginosa, MRSA	Cohorting w/ feedback
Arruda, 2019 ²³	Brazil	PQE, Tertiary [188] hospital wide	En Multiple MDROs	Cohorting only

UK- United Kingdom, US- United States, Aus- Australia, Neth-Netherlands, QE- quasi-experimental, R- retrospective, PQE-prospective quasi-experimental, CC- case-control, MC- multi-center, ICU-intensive care unit, Ob- Outbreak, End-Endemic, P- patient, S-staff, CDI- C. difficile infection, CRE – Carbapenem Resistant Enterobacteriaceae, CR-KPN- Carbapenem Resistant *Klebsiella pneumoniae*, MRSA- Methicillin Resistant *Staphylococcus aureus*, Abau- *A. baumannii*, ESBL-Extended Spectrum Beta-Lactamase, GN- gram-negative, MDRO-Multi-drug Resistant Organism; ESKAP: E. coli/ *Staphylococcus*/KPN/Abau/*Pseudomonas aeruginosa*, VRE-Vancomycin Resistant *Enterococcus*, PD – Patient days RR- Relative Risk, OR- Odds Ratio,

Table 3:

Description of Cohorting Strategy by Pathogen

Author, year	COHORT AREA Separate (S) Geographic (G)		P	S	PS	Cohorting in phases (Yes or No)	DESCRIPTION of COHORTING
	S	G	Patient (P) staff (S), or both (PS)				
C. difficile							
Struelens, 1991		✓	✓			Y	
Cherifi, 2006	✓				✓	N	
Debast, 2009	✓		✓			N	
Price, 2010	✓				✓	N	The cohorting ward was specifically for patients with CDI. Patients testing positive for CDI who still had ongoing diarrhea were transferred to the cohort ward on the same day. The ward had its own nursing staff and all patients admitted to the ward were transferred to the care of the infectious diseases team. All staff working on the ward wore scrubs and put on a new apron and gloves between each patient contact. A small minority of CDI patients had health needs, most usually surgical or high-dependency, which prevented transfer to the ward; however, all patients eligible for transfer to the ward were accommodated there.
Islam 2013	✓				✓	N	11 bed cohort ward: This had two four-bedded bays providing separate female and male areas, a double bay and one side-room. All patients had their own commode, stethoscope and disposable bed curtains.
Garcia-Lecona 2018	✓		✓			N	Common isolation unit (CIU)- A CIU consisted of 1 room with 4 beds was designated for CDI patients. The CIU had 1–2 nurses and 1 medical attendant per shift.
MRSA							
Selkon, 1980	✓				✓	N	The unit has eight single cubicles and two double rooms, all with ante-rooms and en suite toilet and shower facilities. The windows are sealed, ventilation being provided by a plenum system in which air is released into the corridor and then passes through grilles on the doors into the ante-room and then to the patient's room (providing 10 air changes per hour). The air is removed from the patient's room through a central exhaust system and discharged at roof height: Each ante-room is fitted with a wash-hand basin and everyone entering the room puts on a gown and removes it on leaving this area. The nursing and ancillary staff are permanently employed on the unit.
Arnow, 1982		✓			✓	N	
Duckworth, 1988	✓	✓	✓			Y	The isolation bay was located at the end of the ward and had a maximum of five patients at any one time and was open for 7 weeks. The Isolation ward was 14-bed capacity, and was opened during phase 5 of the intervention
Murray-leisure, 1990	✓				✓	Y	In 10/1998 a single unit was established
Cohen, 1991	✓		✓			Y	Cohorting was done only until 1985
Faoagali, 1992	✓	✓	✓			Y	Cohort ward was separate from main hospital, but on campus

Author, year	COHORT AREA (S) Geographic (G)		P	S	PS	Cohorting in phases (Yes or No)	DESCRIPTION of COHORTING
	S	G	Patient (P) staff (S), or both (PS)				
Cox, 1995	✓				✓	N	Though the cohort area was completely separated from the ward by double doors, and had a separate team of nurses, cases continued to occur in the main ward, particularly in the adjacent bay. A vacant ward in a more isolated part of the hospital site was therefore refurbished and the patients moved there.
Mayall, 1996		✓			✓	Y	Positive patients were cohorted into two four-bed bays at one end of the ward. A four-bed bay was left vacant between these patients and other patients from whom MRSA was not isolated: this was reopened in mid-January. Previously colonized patients remained cohorted until discharge. Nurses assigned to these two bays for a single shift did not work elsewhere.
Meier, 1996		✓	✓			N	
Farrington, 1998		✓			✓	Y	
Fitzpatrick, 2000	✓		✓			N	Cohorting in a separate MRSA cohort ward – comprised of three open plan three-bedded areas with assisted and ambulant showering facilities, two single rooms with en suite facilities, a staff changing room with showering facilities, and a rehabilitation room, incorporating physiotherapy and occupational therapy facilities which converts to a patient recreation room after hours.
Cepeda, 2005		✓			✓		
Curran, 2006		✓			✓	N	Cohort w/ in the unit
Singh, 2006		✓	✓			N	
Raineri, 2007		✓	✓			Y	From 1 January 1996 to 31 December 2002, the ICU was divided into two five-bed bays. From 1 January 2003 the ICU moved to another floor, where it was structured into two single rooms, one two-bed and two three-bed bays. MRSA-positive patients, either colonized or infected, were always isolated in single rooms or cohorted in the same bay
Gilroy 2009	✓		✓			N	A cohort unit with 17 private rooms, each with a bathroom; contact precautions was only for those colonized w/ other MDRO
Khan, 2009		✓			✓	Y	
Batra, 2010		✓	✓			Y	
Kusachi, 2010		✓	✓			Y	
Barbut, 2013		✓	✓			N	
Fisher, 2013		✓	✓			N	Patients were placed in isolation or, more usually, in a designated cohort cubicle, established on each ward.
Marshall, 2013		✓	✓			N	
VRE							
Karanfil, 1992		✓			✓	N	
Lai, 1998		✓			✓	Y	

Author, year	COHORT AREA Separate (S) Geographic (G)		P	S	PS	Cohorting in phases (Yes or No)	DESCRIPTION of COHORTING
	S	G	Patient (P) staff (S), or both (PS)				
Jochimsen, 1999	✓				✓	N	Patients were cohorted on a single hospital ward with dedicated nursing staff and patient-care equipment. Patients requiring many different levels of care, from intensive care to rehabilitation, were placed on the same unit
Montecalvo, 1999		✓			✓	N	
Bartley, 2001		✓			✓	N	A six-bed bay in the Infectious Diseases ward was converted into a VRE-only hemodialysis facility.
Ridwan, 2002		✓			✓	N	
Sample, 2002		✓			✓	Y	
Timmers, 2002		✓			✓	Y	The first cohort consisted of all "known VRE-positive" patients. Additionally, patients who had been hospitalized between November 1998 and August 1999 were considered "possibly VRE-positive", irrespective of culture results. They were cohorted and barrier nursed. No sharing of any article between patients was allowed in this patient group. New patients, who had never been admitted to the hematology ward before, were considered to be a "true VRE negative" cohort," and were nursed in separate rooms, without isolation precautions. Nurse cohorting: On every shift nurses were strictly allocated to either VRE-positive or -negative patients. Clinicians conducted their rounds visiting the VRE-negative patients first, followed by the "possibly colonized patients" and the VRE- positive patients last.
Christiansen, 2004	✓				✓	N	3 cohorts established - Positive patients were transferred into dedicated isolation wards where strict contact gown and glove precautions were maintained. Patients who had been in the same ward as positive patients were accommodated in designated "contact" wards. Patients who had not been admitted to Royal Perth Hospital previously during the outbreak, those who had not been in contact with a carrier, and those who had had four negative rectal swabs were placed in designated "clean" wards. Standard precautions were practiced in the latter two patient cohorts. Each cohort had dedicated nursing staff, thus ensuring that movement of nursing staff between VRE-positive and VRE-negative patients did not occur.
Mascini, 2006		✓			✓	Y	P1 (6/2000–10/2000): 4 Cohorts: epidemic VRE (epiVRE) patients, roommates of epiVRE patients, wardmates of epiVRE patients, and newly admitted patients; staff cohorting in 4 cohorts; P2 (11/2000–6/2001): 3 Cohorts: epiVRE patients, possibly epiVRE patients, and newly admitted patients; staff cohorting in 3 cohorts; Preemptive isolation of all patients hospitalized in the ward between January and November 2000, regardless of culture results (patients labeled in hospital information system)
Lucet, 2007	✓				✓	N	All 14 VRE-positive patients in the hospital were cohorted in the rooms opening into one corridor and, later on, in one of the ID units. No other patients were admitted to the cohorting area. Contact precautions were reinforced for these patients according to published guidelines; staff cohorting was done as well.
Schmidt-Heiber, 2007	✓				✓	N	Patients were housed on separate hematologic wards according to their VRE status. Those with an unknown VRE status were housed on a separate ward and then grouped according to the VRE screening results. Each patient cohort was attended by a separate nursing staff.
Kurup, 2008	✓		✓			N	VRE cohorts stretched the capacity of the existing 16-bed isolation ward. Consequently, the latter was extended to a 46-bed ward by temporarily displacing an adjacent colorectal ward.
Servais, 2009	✓				✓	N	
Moretti, 2010	✓				✓	Y	Establishment of a new hospital unit with 14 individual rooms exclusively for VRE patients

Author, year	COHORT AREA Separate (S) Geographic (G)		P	S	PS	Cohorting in phases (Yes or No)	DESCRIPTION of COHORTING
	S	G	Patient (P) staff (S), or both (PS)				
Morris-Downes, 2010		✓	✓			Y	
Chotiprasitsakul, 2016		✓	✓			N	Each unit was divided into 3 zones: confirmed positive VRE zone, VRE-contact zone and non-contact zone. The patients in the confirmed positive VRE and VRE-contact zones had contact precautions implemented, while the patients in the non-contact VRE zone had standard precautions continued.
<i>A baumannii</i>							
Podnos, 2001		✓			✓	N	
Longo, 2005		✓			✓	N	
Apisarnamthan arak, 2008		✓	✓			Y	Cohorting in a section of the unit during period 2
Kohlenberg 2009		✓			✓	Y	Cohorting was started only during second phase
Palmore, 2011		✓			✓	N	
Ayraud-Thevenot, 2012		✓			✓	N	Patients cohorted in a three-bedded area, physically separated from the rest of the unit and with dedicated healthcare workers.
Landelle, 2013	✓				✓	Y	Patient cohorted in a 6- bed isolation unit created in a medical ward and cared for by trained and dedicated healthcare workers
Alfandari, 2014	✓				✓	Y	A second cohorting sector for carbapenem resistant <i>A. baumannii</i> (CRAb) patients was created in an isolated 4-bed sector of the infectious diseases unit.
Apisarnamthan arak, 2014		✓	✓			N	Cohorting of patients in one section of the unit
Cho, 2014	✓		✓			N	4 cohort rooms, of 16 beds dedicated to MDRO
Gray, 2015	✓				✓	N	A cohort ward was created
Molter, 2015		✓			✓	Y	Cohorting (started D4 of outbreak) a designated area for care of patients colonized or infected was defined in the MICU and a separate nursing team took over; cohorting of patients was established to separate patients colonized with CRAb and their contact patients (grey area) from unaffected patients (yellow area).
Gavalda, 2016	✓		✓			N	Cohorting to a unique unit; the cohorting practice was maintained during the entire post-intervention period, even when screening cultures were not systematically performed.
Gagnaire, 2017		✓			✓	N	
Metan, 2019		✓			✓	N	
CRE/ESBL							
Ohana 2006		✓			✓	N	Carriers were cohorted in the same bedrooms or placed in single rooms

Author, year	COHORT AREA (S) Geographic (G)		P	S	PS	Cohorting in phases (Yes or No)	DESCRIPTION of COHORTING
	S	G	Patient (P) staff (S), or both (PS)				
Laurent 2008	✓				✓	N	All colonized patients received cohorted care from a designated nursing staff in a dedicated 6-bed ICU, with additional nurses provided to staff this unit. After 2 weeks, the nursing staff assigned to the cohorted unit was permuted with another team to relieve the staff members from the extra workload and to maintain a high level of compliance with infection control measures.
Kochar 2009		✓			✓	N	Cohorted all patients in adjacent private ICU rooms and assigned dedicated nursing staff.
Langer 2009		✓			✓	N	Cohorting separately case and contact patients.
Carbonne 2010		✓	✓			N	Patients with infection or colonization were placed in a cohort in 1 unit with a dedicated nursing staff.
Gregory 2010	✓				✓	N	Defined 5 distinct sections (cohorting); Nursing staff was assigned exclusively to one of the five sections.
Kassis 2010		✓			✓	Y	Cohorted in an open, 4-patient pod. Respiratory therapists, nursing staff, and nursing aids were also cohorted during their shifts and on a rotating basis, to care exclusively for patients known to harbor KPC-producing <i>K. pneumoniae</i> .
Munoz-price 2010		✓			✓	N	Clinical cases as well as carriers of CRKP were cohorted in separated locations. The cohorted carriers were treated exclusively by dedicated nursing personnel
Agodi 2011		✓			✓	N	Cohorting of CRKP patients with dedicated nursing staff and screening of patients neighboring a patient newly identified as a carrier of CRKP, which was started in March 2007
Ciobotaro 2011	✓				✓	N	Placement of patients in self-contained nursing units—either single rooms or cohorts—containing all materials needed for their care and staffed by dedicated nurses on all shifts.
Cohen 2011		✓			✓	N	
Schwaber 2011		✓			✓	N	
Palmore 2013		✓	✓			N	Nurse cohorting
Sisirak 2013		✓		✓		N	
Vergara-lopez 2013		✓				N	
Kim 2014		✓	✓			N	
Nouvenne 2014	✓				✓	Y	A 14-bed isolation ward with a staff-cohorting management was activated (10/2011–2/2012);
Viale 2014		✓	✓			N	Targeted cohorting of carriers
Hussein 2017		✓			✓	Y	
Decraene 2018	✓				✓	Y	Patient and staff cohorting in dedicated CRE wards (3/2015–12/2015)
Pirs 2018		✓			✓	N	
Reeme 2019	✓				✓	Y	The cohorting unit was an 8-bed hospital ward initially designed for containment of Ebola hemorrhagic fever cases and was used for cohorting KPC cases during this outbreak.

Author, year	COHORT AREA Separate (S) Geographic (G)		P	S	PS	Cohorting in phases (Yes or No)	DESCRIPTION of COHORTING
	S	G	Patient (P) staff (S), or both (PS)				
Other MDROs							
Landrum 2008		✓			✓	N	
Rosenberger, 2011		✓			✓	Y	Patient cohorting/enhanced isolation in ICU (until discharge): The main front entrance was closed, and all traffic was redirected through the back entrance of the unit, decreasing unnecessary flow in the “high-risk” area. Nursing staff assigned to provide care for either two isolation or two non-isolation patients, and no nurse provided care to both an isolation and a non-isolation patient. Staff rounds in the ICU were modified; Procedures and diagnostic tests were performed at the bedside without transportation out of the unit unless absolutely necessary. When a procedure outside the unit was necessary for an isolated patient, his or her exit from the unit was through the previously closed front door to avoid passage in front of the rooms of non-isolated patients
Stumpfs, 2013	✓				✓	N	Patient cohort in a special unit—the 34 beds of the unit were located in 16 rooms for adult MDRO-infected patients and 2 additional rooms for respiratory isolation. Patients were transferred to the unit when they were identified as infected or colonized with MDROs.
Wongchaoren, 2013		✓			✓	Y	8 bed cohort area in the unit, 1 nurse per shift in the area
Arruda, 2019	✓				✓	N	

Summary of Study Outcomes by Pathogen and Endemicity

Pathogen	Cohorting	Pre intervention	Post-intervention	Risk ratio	Outcome
C. difficile					
Outbreak					
Struelens 1991	G	1.47/1000 admissions 1.5/10,000 patient days [PD]	0.39/1000 0.34/10,000	0.26 (0.46–0.87) 0.23 (NR)	Decrease
Cherifi 2006	SU	99 /100,000 [PD]	31/100,000	0.31 (0.13–0.77), p=0.013	Decrease
Debast 2009	SU	45	0	NA	Decrease
Islam 2013	SU	5/110	21/138	3.34 (1.3–8.6) p= 0.021	Increase
Endemic					
Price 2010	SU	1.3/1000 bed days [BD]	0.6/1000	0.46 (NR)	Decrease
Garcia-Lecona 2018	SU	7/91 recurrences	14/85	2.14 (0.91–5.05), p= 0.08	No change
MRSA					
Outbreak					
Selkon 1980	SU	6.5 /1000 patients	0.527/1000	0.08 (NR), p=0.05	Decrease
Amow 1982	G	2.5 /100 PD	0/100 PD	0	Decrease
Duckworth 1988	SU	169	67		Decrease
Murray-Leisure 1990	SU	16 / month Colonization: 6/53 (11.3%)	1–3/month 0/39 (0)	NA 0	Decrease
Cox 1995	SU	35/month	1–2/month	NA	Decrease
Mayall 1996	SU	Colonization: 19%	6.4%	0.34 (NR)	Decrease
Meier 1996	SU	6	0		Decrease
Cohen 1991	G	3.5/1000 discharges	1.5/1000	0.29 (NR)	Decrease
Faoagali 1992	G	11/40131 admissions	720/48818	49 (NR)	Increase
Farrington 1998	G	29% (# cases/# infections)	14%	0.48 (NR)	Decrease
Curran 2006	G	1–7/month	0–2/month	P<0.0005	Decrease
Khan 2009	G	9	0	NA	Decrease
Batra 2010	G	1.06 (1.03–1.08)	A 1.12 (0.632.01) B 0.71 (0.182.88)^ C 3.85 (0.818.59)	NR	No change
Barbut 2013	G	7.22/1000 PD	0.77/1000	P<00001	Decrease
Endemic					

<i>Pathogen</i>	<i>Cohorting</i>	<i>Pre intervention</i>	<i>Post-intervention</i>	<i>Risk ratio</i>	<i>Outcome</i>
Fitzpatrick 2000	SU	NR NR	26/88 (27%) infected decolonized	NA	Not reported
Cepeda 2005	G	Hospital A 20.6/1000 PD Hospital B 28.2/1000 PD	15.5/1000 22.2/1000	A: 0.72[0.44–1.17], p=0.91 B: 0.76[0.37–1.58], p=0.77 (HR)	No change
Singh 2006	G	Acquisition 45.6% Infection 40.4 (19/47)	9.9% 4.1 (4/97)	0.22 (NR), p<0.001 p<0.001	Decrease
Rainieri 2007	G	Bacteremia 25.5 (12/47) 3.5/1000 PD	4.1 (4/97) 1.7/1000 (p2) 0.7/1000 (p3)	p<0.01 P= 0.0023 P=0.048	Decrease
Gilroy 2009	SU	0.66/1000 PD	0.43/1000 0.23/1000	0.65 (NR) 0.53 (NR)	
Kusachi 2010	G	34/833 (4.1%)	D 40/1807 (2.2) E 5/1302 (0.4)	0.18 (NR), p<0.002	Decrease
Fisher 2013	G	Infection 0.26/1000 PD (0.18–0.34) <u>Acquisition 10%</u>	0.11/1000 (0.07–0.19) 5	0.42 0.5 (NR)	Decrease Decrease
Marshall 2013	G	<u>Hand hygiene compliance 47% (44–49)</u> 18.5/1000 risk days <u>Hand hygiene compliance: Glove use 698/795 (87.8%)</u>	69% (68–71) 7.9/1000 12–34% 622/722 (86.2)	14.6 (NR) HR 0.39 (0.24–0.62) NA P=0.3	Improved Improved No change No change
VRE					
Outbreak					
Karanfil 1992	G	6	0	NA	Decrease
Lai 1998	G	24/month <u>Hand hygiene: 51%</u>	2–7/month 100%	NA	Decrease Increase
Bartley 2001	G	49	0	NA	Outbreak
Ridwan 2002	G	<u>MRSA incidence : 10.9/mo</u> 43	19/mo	p=0.013	control 4 mos Increase
Sample 2002	G	3.5/1000 PD	NR	NA	Partial control 4 mos
Timmers 2002	G	24	0.8/1000	0.22 (NR), p=0.001	Decrease; outbreak control 5 mos
Christiansen 2004	SU	169	0		Outbreak control week 44
Mascini 2006	G	P1 NR <u>Hand hygiene: 31%</u>	0		Outbreak control in 6 mos
Lucet 2007	SU	37		PII 0.67 (0.41–1.1) PIII 0.02 (0.002–0.6)	Outbreak control in 3 yrs Increase
Schmidt-Heiber 2007	SU	33	0		Outbreak control 4 wks
			0		Outbreak control 33 wks

<i>Pathogen</i>	<i>Cohorting</i>	<i>Pre intervention</i>	<i>Post-intervention</i>	<i>Risk ratio</i>	<i>Outcome</i>
Kurup 2008	SU	29/254 (11.4%)	6/142 (4.2)		Outbreak control 3 mos
Servais 2009	SU	14	0		Outbreak control 2 mos
Moretti 2010	SU	75.8/1000 PD	0.45/1000	P<0.001	Decrease
Endemic					
Jochimsen 1999	SU	0.28/100 admissions <u>Infection control compliance: 5/23 (21%)</u>	0.09/100 36/41 (88%)	0.32 (0.69–15.85), p=0.2 p<0.001	No change Decrease
Montecalvo 1999	G	<u>Infection 2.1/1000 PD</u>	0.45/1000	0.22 (0.05–0.92), p=0.04	Decrease
		<u>Colonization 20.7/1000 PD</u>	10.3/10000	0.5 (0.33–0.75), p <0.001	Decrease
	G	<u>Colonization 1.96/10,000 BD (2001)</u>	4.98/10,000 (2006) 3.18/10,000 (2007)	P<0.01 (2006 vs 2007)	Decrease
Morris-Downes 2010		<u>BSI</u> 0.091 (2001)	0.78 (2005)	P < 0.001	Increase
Chotiprasitsakul 2016	G	<u>Hand hygiene 28% (20050)</u>	88 (67–93) [2008]	NR	Increase
<i>A. baumannii</i>					Outbreak control 33 wks
Endemic					
Apisarnthanarak 2008		<u>Colonization/Infection</u> 3.6/1000 PD	P2 1.2/1000 P3 0.85/1000	P<0.001	Decrease
	G	<u>Hand hygiene</u> –0.31 +/- 0.7	P2 0.75 +/- 0.8 P3 0.54 +/- 0.1	NR	No change
		<u>Infection rates</u>	P2 1.74/1000	p<0.001	Decrease
		P1 11.1/1000 PD	P3 0.69/1000	p<0.001	
Apisarnthanarak 2014	G	<u>Surveillance</u> P1 12.15/1000PD	P2 2.11/1000 P3 0.98/1000	p<0.001	Decrease
		<u>Hand hygiene</u>	P2/P3	NS	No change
		<u>Infection rates</u>	0.46/1000	P=0.96 (2010)	No change
		0.35/1000 PD (2007)	0.06/1000	P<0.001 (2012)	Decrease
Cho 2014	SU	<u>Hand hygiene: 5.6L/1000 PD</u>	7.5/1000 11.9/1000	P<0.001 (2012)	Decrease
Gavalda 2015	SU	10.78/1000 PD (2011)	5.87/1000 1.74/1000 0.69/1000	0.54 (0.41–0.73) (2012) 0.3 (0.18–0.48) (2013) 0.4 (0.18–0.89) (2014), p<0.02	Decrease
Outbreak					

<i>Pathogen</i>	<i>Cohorting</i>	<i>Pre intervention</i>	<i>Post-intervention</i>	<i>Risk ratio</i>	<i>Outcome</i>
Podnos 2001	G	52	0		Outbreak control 13 mos
Longo 2005	G	14	0		Outbreak control ; 2 mos
Kohlenberg 2009	G	32	0		Outbreak control 10 mos
Palmore 2011	G	Total 63 1 st outbreak 29 2 nd outbreak 22	0 0		Control in 6 mos 3 mos
Ayraud-Thevenot 2012	G	1 st outbreak = 20	2 nd outbreak= 7		Outbreak control 152 days vs. 25 days
Landelle 2013	SU	38	0		Outbreak control 18 mos
Alfandari 2014	SU	8	0		Outbreak control 9 mos
Gray 2015	SU	29	0		Outbreak control 20 mos
Moller 2015	G	10	0		Outbreak control 1 mo
Gagnaire 2017	G	5	0		Outbreak control 37 days
		VAP 10.19/1000 PD	3.645/1000	P=0.198	No change
Metan 2019	G	CLABSI 14.33 CAUTI 11.05 <u>Hand hygiene 58%</u>	12.90/1000 6.858/1000 62%	P=1 P=0.27 p=0.38	No change No change No change
Enterobacteriaceae					
Ohana 2006	G	2.36/1000 PD (2000–2002)	0/1000 (2003)	0	Decrease
Laurent 2008	SU	11.57/1000 PD	0.08/1000	0.11 (NS)	Decrease
Kocher 2008	G	9.7/1000 PD	3.7/1000	0.38 p<0.001	Decrease
Langer 2009	G	8.6/1000 PD	0		Decrease
Carbonne 2010	G	13	0		Outbreak control in 1 mo
		26	0		Outbreak control in 7 mos
Gregory 2010	SU	<u>Hand hygiene (no baseline)</u> <u>Contact precaution (no baseline)</u>	108/225 (48%) 139/225 (62%)		Not indicated
Kassis 2010	G	8	0		Outbreak control after 1 yr
Munoz-price 2010	G	10	0		Outbreak control in 7 mos
Agodi 2011	G	16	0		Outbreak control in 4 mos
Ciobotaro 2011	SU	3.4/10000 – 8.2/10000 PD 30/1000 hospital beds	0.5/10000 P2 13.4	0.91 (0.85–0.97), p<0.001 p<0.001	Decrease Decrease

<i>Pathogen</i>	<i>Cohorting</i>	<i>Pre intervention</i>	<i>Post-intervention</i>	<i>Risk ratio</i>	<i>Outcome</i>
Cohen 2011	G	Compliance w/ cohorting w/ active surveillance	P3 8.3 P4 4.3	p=0.76 p=0.27 71 +/- 20 43 +/- 10	No change No change Not reported
Schwaber 2011	SU	55.5/100,000 PD	11.7	0.21 (NR) p<0.001	Decrease
Palmore 2013	G	8 then 15	0		Outbreak control 1 yr
Sisirak 2013	G	Hand hygiene: 84–88%	Close to 100%		Increase
Vergara-Lopez 2013	G	78	0		Outbreak control 1 yr
Kim 2014	G	1.91/100 PD	1.24/100 P2 0.82/100 P3	NR	Decrease
Nouvelle 2014	SU	5.49 to 9.81/100,000 PD	1.61/100,000	0.88 (NR) p<0.001	Decrease
		Hand hygiene: 35.2	78%		Increase
		18–23/ month (13.2–16.9% incidence)	3–13 (8/month, 1.2%)	P=0.04	Decrease
Viale 2014		Infection rate : 36.6%	22.5%	P= 0.07	No change
		CRE BSI 1.05 (0.99 – 1.11) p 0.09		IRR 0.96 (0.92–0.99), p=0.03	Decrease
	G	CRE Colonization NR		0.96 (0.95–0.97), p<0.0001	Decrease
Hussein 2017	G	CRE incidence 186.6 /100,000 HD	23.4/100,000	p<0.05	Decrease
		CRE BSI 25.5/100,000 HD	3.7–4.4/100,000	p<0.05	Decrease
		<i>E. coli</i> 0.15 (0.04–0.67)	0.02 (0–0.14)	p<0.001	Decrease
Decraene 2018	SU	KPN 0.19 (0.04–0.82)	0.27 (0.090.78)	p=0.015	Decrease
Pirs 2018	G	42	0		Outbreak control 6 mos
Reeme 2019	SU	8	0		Outbreak control 9 mos
Other MDRO					
Outbreak					
Rosenberger 2011	G	6	0		Outbreak control 2 mos
Endemic					
Landrum 2008	G	VAP 60.6/1000 PD	11.1/1000	0.18 (NR), p=0.029	Decrease
Stumpfs 2013	SU	MDRO incidence: 0.65 VRE 0.69	–1.04 –1.04	p<0.01 p<0.01	Decrease Decrease
	SU	Hand hygiene 54%	66%	p<0.05	Increase
Wongchaoren 2013		Gloves 16.7%	37.2%	p<0.05	Increase

<i>Pathogen</i>	Cohorting	Pre intervention	Post-intervention	Risk ratio	Outcome
Arruda 2019	SU	Environmental cleaning 90%	90%	NR	No change
		2/1000 PD	2.8/1000 PD	IDR 1.35 (1.01–1.810, p=0.04	Decrease

G- geographic, SU- special or dedicated unit; NR – Not reported, RR Risk ratio, IDR – incidence density ratio Bolded- cohorting intervention