Beyond the cloudiness in urinary tract infection: definitions, diagnostics, and strategies for prevention

Bilsen, M.P.

Chapter 7

Faecal microbiota replacement to eradicate antimicrobial resistant bacteria in the intestinal tract – a systematic review

Manu P. Bilsen, Merel M.C. Lambregts, Joffrey van Prehn, Ed J Kuijper

Curr Opin Gastroenterol. 2022 Jan 1;38(1):15-25

Abstract

Purpose of review

Antimicrobial resistance (AMR) is a rising threat to global health and is associated with increased mortality. Intestinal colonisation with multidrug-resistant organisms (MDRO) can precede invasive infection and facilitates spread within communities and hospitals. Novel decolonisation strategies, such as faecal microbiota transplantation (FMT), are being explored. The purpose of this review is to provide an update on how the field of FMT for MDRO decolonisation has developed during the past year, and to assess the efficacy of FMT for intestinal MDRO decolonisation.

Recent findings

Since 2020, seven highly heterogenous, small, non-randomised cohort studies and five case reports have been published. In line with previous literature, decolonisation rates ranged from 20-90% between studies, and were slightly higher for CRE than VRE. Despite moderate decolonisation rates in two studies, a reduction in MDRO bloodstream and urinary tract infections was observed.

Summary and implications

Although a number of smaller cohort studies show some effect of FMT for MDRO decolonisation, questions remain regarding the true efficacy of FMT (taking spontaneous decolonisation into account), the optimal route of administration, the role of antibiotics pre- and post-FMT and the efficacy in different patient populations. The observed decrease in MDRO infections post-FMT warrants further research.

Introduction

Antimicrobial resistance (AMR) is a rising and significant threat to global health. [1] In addition to the considerable economic burden, AMR is associated with increased morbidity and mortality. [2] In Europe, more than half of *E. coli* isolates are resistant to at least one antimicrobial group and 7.9% of *Klebsiella pneumoniae* isolates are carbapenem resistant. Moreover, there is a worrisome increase in vancomycin-resistant *Enterococcus* (VRE) (18.3%) and infections with extended-spectrum beta-lactamase producing *Enterobacteriaceae* (ESBL-E). [3, 4] Intestinal colonisation with multidrug-resistant organisms (MDRO) facilitates spread of MDRO within communities and hospitals. In both immunocompetent and immunocompromised hosts, gut colonisation can result in invasive infections, with high morbidity and mortality. [5, 6] In a retrospective, single-centre study including 107 patients undergoing allogeneic stem cell transplantation (allo-SCT), 31% of patients were colonised with at least one MDRO. Compared to non-colonised patients, colonised patients more frequently experienced bacteraemia post-SCT (48% versus 24%) and had a significantly worse two-year overall survival (34% versus 74%), with infection being the leading cause of death. [7]

To prevent infections with MDRO, strategies to combat MDRO colonisation must be explored. The current ESCMID guideline does not recommend the use of non-absorbable antibiotics for MDRO decolonisation, as the available evidence on its efficacy is insufficient. [8] More importantly, non-absorbable antibiotics can contribute to selection of AMR bacteria with subsequent spread to the environment and other individuals. [9]

Faecal microbiota transplantation (FMT) has been shown to be an effective treatment for patients with recurrent *Clostridioides difficile* infection (rCDI), a condition that is characterised by an antibiotic-induced disruption of commensal gut microbiota, i.e. dysbiosis. [10] Compared to healthy stool donors, rCDI patients have decreased microbiota diversity and increased numbers of antibiotic resistant genes. In these patients, FMT increases microbiota diversity, while decreasing the number of antibiotic resistance genes. [11, 12] Contrary to rCDI, less is known about the degree of dysbiosis in individuals with MDRO colonisation, though some studies report decreased species richness in this population as well. [13, 14] Several small studies, including one randomised controlled trial (RCT) [15], have explored whether FMT is an effective modality to decolonise patients with MDRO, as summarised by several recent reviews. [16-18] These reviews conclude that

FMT is a promising treatment strategy for MDRO decolonisation, although the RCT by Huttner et al. [15] did not find a significant difference, but was terminated early. Conclusions are hampered by the major heterogeneity of studies regarding definition of (de)colonisation, type of MDRO, route of administration, number of transplantations, periprocedural treatment with antibiotics, and duration of follow-up.

The objective of this review is to provide an update on how the field of FMT for MDRO decolonisation has developed during the past year, by highlighting recently published and ongoing studies, ultimately to assess whether FMT is an effective treatment strategy for intestinal MDRO decolonisation. Adding to the recent overview provided by Dharmaratne et al. [18], this review includes several newer studies, as well as studies with paediatric patients.

Methods

This systematic review was conducted in accordance with the *Preferred Reporting Items for Systematic reviews and Meta-analyses* (PRISMA) 2020 guidelines. [19] Details of the protocol for this systematic review were registered in PROSPERO. [20]

Eligibility criteria

We included all studies investigating the efficacy of FMT for intestinal MDRO decolonisation. This included clinical trials, cohort studies and case reports in adult and paediatric patients with intestinal MDRO colonisation, including carbapenem-resistant *Enterobacteriaceae* (CRE), carbapenem resistant non-fermenters (*Pseudomonas* and *Acinetobacter* spp.), VRE and ESBL-E, confirmed by at least one positive stool sample or rectal/perianal swab. Studies involving immunocompromised patients were eligible for inclusion. We excluded studies only investigating patients colonised with both *Clostridioides difficile* and MDRO, since extreme dysbiosis would be likely in this population. For our intervention (FMT) we considered all routes of administration: oral (capsule), nasogastric/duodenal, via colonoscopy or enema. We applied no restrictions to pretreatment (antibiotics, proton pump inhibitor (PPI) and bowel lavage), stool volume, fresh or frozen stool, donor relationship or number of transplantations. Studies only investigating other microbiota-altering treatments, such as probiotics and non-absorbable antibiotics, were ineligible.

To be included, a study had to report the number of decolonised patients, confirmed by at least one stool sample or rectal/perianal swab post-FMT. Studies reporting the number of MDRO infections post-FMT, e.g. in patients with recurrent urinary tract infections, were only included if they also reported intestinal (de)colonisation. We also included unpublished manuscripts, conference abstracts and ongoing trials. To avoid language bias, studies published in non-English language journals were eligible for inclusion if one of the team members could read the foreign language (French, Spanish, German and Dutch). All study settings (community, outpatient and inpatient) were allowed. We excluded studies published before 2020, since a recent meta-analysis has been performed with studies published before 2020. [18] Finally, we excluded murine (or other animal) studies, reviews and meta-analyses.

Search strategy

Multiple electronic databases were searched May 19th 2021; these included PubMed, Embase, Web of Science, the Cochrane Library, and Academic Search Premier [21]. The search strategy, based on a PICO-style approach, was constructed by librarian specialised in literature searches and is provided in the **Supplement**. Next, a 'snowball' search was performed to identify additional studies by searching reference lists of study reports included in this systematic review or earlier reviews on the same topic. For ongoing trials clinicaltrials.gov was searched July 1st 2021, using the following keywords: 'faecal microbiota transplantation' and 'resistance'. No filters regarding start date were applied, as we did not want to miss ongoing trials that had started before 2020. The entire search was updated in August 2021.

Data extraction and analysis

After removal of duplications in EndNote, references were imported into Covidence software. Title/abstract and full-text screening was performed independently by two reviewers (M.P.B., M.M.C.L.). In case of disagreement, a third researcher was consulted (E.J.K.). A data extraction form was designed, after which one reviewer (M.P.B.) carried out the data extraction using Covidence. For each study, the following data was collected: study design, eligibility criteria, population characteristics, number of participants, type of pathogen, definition of (de) colonisation, detection technique, FMT route of administration, pretreatment, stool volume and type, donor type, decolonisation rate, MDRO infection rate,

microbiota composition and duration of follow-up. The Newcastle Ottawa Scale, addressing three specific domains (i.e. selection, comparability and outcome), was used for assessing risk of bias in cohort studies. [22] Risk of bias was assessed by one reviewer (M.P.B.), but in case of uncertainty, a second reviewer was consulted (M.M.C.L.). A meta-analysis was not undertaken due to significant heterogeneity regarding study design, population and intervention, and a paucity of included studies. A narrative summary of the data is provided below.

Results

Study selection process

The study selection process is summarised in a PRISMA flowchart (**Figure 1**). Most records that were excluded during title and abstract screening involved patients with rCDI. During full-text screening, 35 reports were excluded that either did not include our target population, e.g. patients not colonised with MDRO and receiving FMT for different indications, or did not report intestinal decolonisation rate, e.g. investigating post-FMT faecal composition or decolonisation of extra-intestinal sites instead. Finally, a total of 36 studies were included: seven cohort studies [23-29], five case reports [30-34], and 24 ongoing trials.

Study characteristics

A complete overview of the included cohort studies and case reports is provided in **Table 1**, and ongoing trials are summarised in **Supplementary Table 1**. A total of 254 patients were assessed in the included cohort studies and case reports, with only one study investigating paediatric patients. [28] Eight studies included immunocompromised patients, mostly undergoing allo-SCT [24, 25, 28, 30-34], and three studies included a total of 14 patients with concurrent rCDI. [25, 27, 29] While most studies required one positive stool culture or rectal/perianal swab for the definition of colonisation, decolonisation was often confirmed by serial cultures or swabs. Most patients were colonised with CRE (n = 119), followed by VRE (n = 61), both CRE and VRE (n = 21), ESBL-E (n = 14), and multidrug resistant *Pseudomonas aeruginosa* (n = 1). Ghani et al. [25]* did not specify the type of MDRO for their control group. To the best of our knowledge, the study by Wang et al. [34] is the first study investigating the efficacy of FMT for gut eradication of a hypervirulent *Klebsiella pneumoniae* strain.

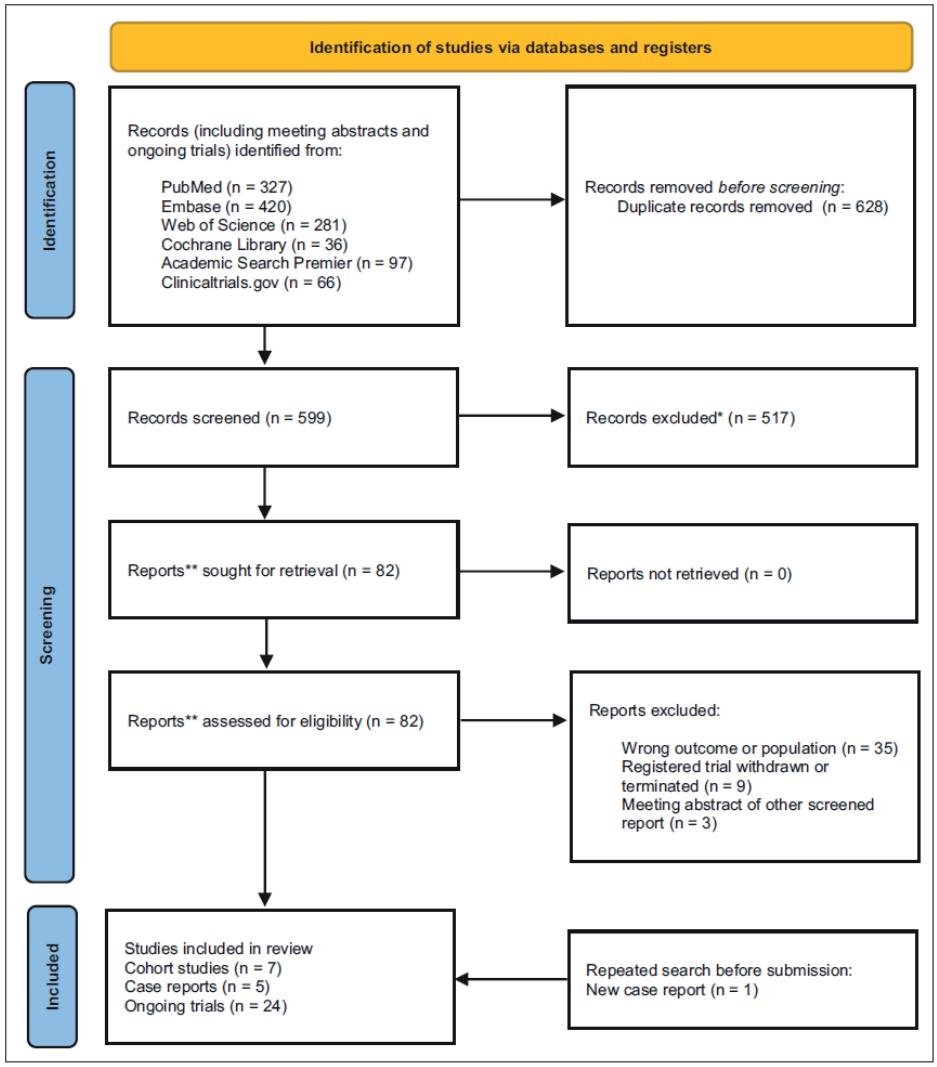

Figure 1: PRISMA flowchart of study selection process. *Large number of records involved patients with recurrent *C. difficile*. **In case of ongoing trials, we assessed the study protocol for eligibility.

Table 1: Overview of included cohort studies and case reports.

First author & year	Study design	Population	Number of participants	Number of culture/PCR to define (de) colonisation	Type of pathogen*	FMT procedure**	Pretreatment	Antibiotic use post-FMT	Decolonisation rate	Number of MDRO infections post-FMT
Lee 2020 Korea (23)	Prospective cohort study with control group	Adult patients with CRE or VRE colonisation Median age, gender, immune status not reported	Total (n = 38) FMT (n = 21) Control (n = 17)	Colonisation: 2 Decolonisation: NR	FMT cohort: CRE (n = 13, not further specified), VRE (n = 5), CRE and VRE (n = 3) Controls: CRE (n = 7), VRE (n = 10)	NR	NR	NR	FMT: 8/20 (40%) at 1 month, 10/14 (71.4%) at 3 months Controls: 0/14 (0%) at 1 month, 1/9 (11.1%) at 3 months	NR
Bar-Yoseph 2020 Israel (24)	Prospective cohort study with control group	Adult patients with CRE colonisation Median age: 62 years Male gender: 53% Immunocompro-mised: 20.5%	Total (n = 39) FMT (n = 15) Control (n = 24)	Colonisation: 1 Decolonisation: 3	FMT cohort: *Klebsiella pneumoniae* (n = 7), *Enterobacter* spp. (n = 3), *E. coli* (n = 2), *Serratia marcescens* (n = 2), *Klebsiella oxytoca* (n = 1) Controls: *Klebsiella pneumoniae* (n = 19), *Enterobacter* spp. (n = 2), *E. coli* (n = 3), *Citrobacter freundii* (n = 1)	Oral (15 capsules per day for 2 consecutive days) Stool: 25-30 gram, frozen, unrelated donor	AB: no BL: no PPI: yes	FMT cohort: 5/15 (33.3%) Controls: 21/24 (87.5%)	FMT: 9/15 (60%) at 1 month, 8/12 (66.7%) at 6 months Controls: 10/24 (41.7%) at 1 month, 7/13 (53.8%) at 6 months	FMT: 0/15 Controls: 9/24 (37.5%)

Table 1: Continued

First author & year	Study design	Population	Number of participants	Number of culture/PCR to define (de) colonisation	Type of pathogen*	FMT procedure**	Pretreatment	Antibiotic use post-FMT	Decolonisation rate	Number of MDRO infections post-FMT
Ghani 2020 United Kingdom (25)	Prospective cohort study with control group	**Group 1:** Haematology patients (mostly allo-HSCT) with CRE, VRE or ESBL colonisation **Group 2:** Patients with MDRO-mediated rUTI, mostly renal transplant recipients, no current infection **Controls:** similar patients but not undergoing FMT Median age 62.5 years Male gender 55% Immunocompromised: 76% rCDI (n = 4)	Total (n = 60) Group 1 (n = 11) Group 2 (n = 9) Control (n = 40)	NR (just 'serial rectal swabs')	Group 1: CRE (n = 8, including *E. coli*, *Citrobacter freundii* and *Klebsiella* spp.) VRE (n = 3) or ESBL *E. coli* (n = 2) Group 2: ESBL (n = 9): *E. coli* (n = 7), *Klebsiella pneumoniae* (n = 2)	Upper endoscopy/ naso-duodenal tube Stool: 50 gram, frozen, unrelated donor, 1–2 FMTs per patient	AB: discontinued 24h prior BL: yes PPI: yes	Yes, almost all patients, no absolute number (or specific antibiotic) is reported	7/17 (41%) of group 1 and 2 patients were decolonised (follow-up range 6 weeks - 24 months), NR for control group	Significant reduction in BSI (absolute number NR) and MDRO UTIs (pre-FMT median = 4 ± 2 episodes, post-FMT median = 1 ± 2 episodes) in group 1 and 2 compared to controls.
Seong 2020 Korea (26)	Prospective cohort study with control group	Adult patients with CRE or VRE colonisation Median age: 69 years Male gender: 53% Immunocompromised: none	Total (n = 83) FMT (n = 35) Control (n = 48)	Colonisation: 1 Decolonisation: 2	FMT cohort: VRE 19/35 (54.3%), CRE 4/35 (11.4%), both 12/35 (34.3%) Controls: VRE 24/48 (50%), CRE 20/48 (41.7%), both 4/48 (8.3%)	At the discretion of the physician: upper endoscopy, oral or colonoscopy Stool: 100 gram, frozen, unrelated donor, 1 FMT per patient	AB: 45% in the week prior BL: yes if colonoscopy PPI: yes if upper endoscopy	19/35 (54.3%) in the week post-FMT	FMT: 65.7% at 6 months, 68.6% at 12 months Controls: 25.0% at 6 months, 27.1% at 12 months	NR

Table 1: Continued

First author & year	Study design	Population	Number of participants	Number of culture/PCR to define (de) colonisation	Type of pathogen*	FMT procedure**	Pretreatment	Antibiotic use post-FMT	Decolonisation rate	Number of MDRO infections post-FMT
Lee 2021 Korea (27)	Prospective cohort study without control group	Adult patients with CRE or VRE colonisation Median age: 75 years Male gender: 30% Immunocompromised: NR rCDI (n = 2)	N = 10	Colonisation: NR Decolonisation: 3	*Klebsiella pneumoniae*, carbapenemase producing (n = 8), VRE and *Klebsiella pneumoniae* (n = 2)	Colonoscopy (n = 9), upper endoscopy (n = 7), 20 capsules (n = 1) Stool: volume NR, frozen, unrelated donor, 1–3 FMTs per patient	AB: discontinued 48h prior BL: yes PPI: no	NR	4/10 at 1 month, 5/10 at 3 months and 9/10 at 5 months after initial FMT	NR
Merli 2020 Italy (28)	Prospective cohort study without control group	Paediatric patients scheduled to undergo allo-HSCT, some having a history of systemic infections with MDRO Median age: 11 years Male gender 80% Immunocompromised: 100%	N = 5	NR (just 'weekly rectal swabs)	Carbapenemase resistant: *E. coli* (n = 3), *Klebsiella pneumoniae* (n = 2), *Klebsiella oxytoca* (n = 1), *Klebsiella ornithinolytica* (n = 1), *Enterobacter cloacae* (n = 1), *Pseudomonas aeruginosa* (n = 1)	Upper endoscopy/ naso-duodenal tube Stool: 100–240 mL, frozen (80%), unrelated donor, 1 FMT per patient	AB: yes, 80% received oral colistin for 3 days BL: no PPI: no	Yes, broad-spectrum antibiotic prophylaxis with piperacillin/ tazobactam when neutrophils <500/µl or fever	4/5 (80%) at 1 week, 1/5 (20%) at 1 month	1 episode in 1 patient

Table 1: Continued

First author & year	Study design	Population	Number of participants	Number of culture/PCR to define (de) colonisation	Type of pathogen*	FMT procedure**	Pretreatment	Antibiotic use post-FMT	Decolonisation rate	Number of MDRO infections post-FMT
Silva 2020 Portugal (29)	Retrospective cohort study	Adult patients with CRE colonisation Median age: 66 years Male gender: 38.4% Immunocompromised: none rCDI (n = 8)	N = 13	Colonisation: 1 Decolonisation: 3	CRE, not further specified	Upper endoscopy/ naso-duodenal tube Stool: 50 mL, fresh, unrelated donor, number of FMTs NR	AB: only for rCDI patients (until the day before FMT) BL: yes PPI: yes	No	Total: 10/13 (77%) Without rCDI (CRE carriers only): 4/5 (80%), median time to decolonisation 16 weeks	0

Table 1: Continued

First author & year	Study design	Population	Number of participants	Number of culture/PCR to define (de) colonisation	Type of pathogen*	FMT procedure**	Pretreatment	Antibiotic use post-FMT	Decolonisation rate	Number of MDRO infections post-FMT
Biernat 2020 Poland (30)	Case report	Both patients underwent allo-HSCT (one for AML, one for osteomyelofibrosis) Median age: 28.5 years Male (both patients) Immunocompromised: 100%	N = 2	Colonisation: 1 Decolonisation: 1	Case 1: ESBL *E. coli* and ESBL *Klebsiella pneumoniae* Case 2: ESBL *Enterobacter cloacae*	Upper endoscopy/ naso-duodenal tube Stool: 100 gram, fresh, unrelated donor, 3-4 FMTs per patient	AB: stopped prior to FMT (but recent broad spectrum treatment) BL: no PPI: yes	Yes	Case 1: Eradication of ESBL *E. coli* after first FMT and eradication of ESBL *Klebsiella* after third FMT. Acquired VRE after second FMT, eradicated after third. Colonised with MDR *Acinetobacter baumannii* after third FMT Case 2: Eradication of ESBL *E. cloacae* after first FMT, acquired VRE and ESBL *E. coli* after second and third FMT, eradicated after fourth FMT	1/2 Case 1 died due to *Acinetobacter. baumannii* BSI

Table 1: Continued

First author & year	Study design	Population	Number of participants	Number of culture/PCR to define (de) colonisation	Type of pathogen*	FMT procedure**	Pretreatment	Antibiotic use post-FMT	Decolonisation rate	Number of MDRO infections post-FMT
Bilinski 2020 Poland (31)	Case report	Adult with AML undergoing allo-HSCT Age: 36 years Male Immunocompromised: yes	N = 1	Colonisation: 1 Decolonisation: 3	CRE (*Klebsiella pneumoniae*, NDM-1)	Upper endoscopy/ naso-duodenal tube Stool: 100 gram, fresh, unrelated donor, 2 FMTs	AB: no BL: yes PPI: yes	Yes, metronidazole after first FMT	1/1 at 2 weeks but reappeared after chemotherapy and antibiotic prophylaxis. After a second FMT the patient remained decolonised at 6 months	0
Keen 2020 United States (32)	Case report	Patient with rUTI due to ESBL *Klebsiella pneumoniae*. History of kidney and liver transplantation Age: 62 years Female Immunocompromised: yes	N = 1	Colonisation: 1 Decolonisation: NR (but patient was tested multiple times)	ESBL *Klebsiella pneumoniae*	Enema Stool: single 150 mL suspension (> 10^7 organisms per mL), frozen, unrelated donor, 1 FMT	AB: suppressive ertapenem until 2 days prior to FMT BL: no PPI: no	Yes, oral amoxicillin 6 weeks post-FMT, then intravenous vancomycin, piperacillin/ tazobactam 8 weeks post-FMT and amoxicillin/ clavulanate, followed by cefepime and metronidazole 10 weeks post-FMT	0/1 at 1 month and 4 months post-FMT	2

Table 1: Continued

First author & year	Study design	Population	Number of participants	Number of culture/PCR to define (de) colonisation	Type of pathogen*	FMT procedure**	Pretreatment	Antibiotic use post-FMT	Decolonisation rate	Number of MDRO infections post-FMT
Su 2021 China (33)	Case report	Patient with AML undergoing allo-HSCT, colonised with CRE prior to conditioning therapy, identified on routine rectal screening. Age: 45 years Male Immunocompromised: yes	N = 1	Colonisation: 1 Decolonisation: NR (but patient was tested seven times)	Carbapenem resistant *Klebsiella pneumoniae*	Upper endoscopy/ naso-duodenal tube Stool: volume NR, frozen, unrelated donor, 2 courses with 17 day interval (three procedures per course)	AB: no BL: no PPI: no	No	1/1 (stool cultures were CRE negative at 1 week, 1 month, 2 months, 3 months, 6 months, 11 months, and 26 months)	0
Wang 2021 (34)	Case report	Renal transplant patient with CRE bacteraemia and surgical site infection Age: 37 years Female Immunocompromised: yes	N = 1	Colonisation: 2 Decolonisation: 1	Carbapenem resistant and hypervirulent *Klebsiella pneumoniae*	Upper endoscopy/ naso-duodenal tube Stool: volume NR, fresh/ frozen NR, unrelated donor, 1 FMT	AB: meropenem, tigecycline, fosfomycin discontinued 24h prior to FMT BL: yes PPI: yes	No	1/1 at 1 week	0

*May surpass total number of patients as some patients were colonised with multiple MDROs. ** May surpass total number of patients as some patients had multiple FMTs with different procedures. Abbreviations: CRE = carbapenemase resistant Enterobacteriaceae, VRE = vancomycin resistant *Enterococcus*, allo-HSCT = allogeneic haematopoietic stem cell transplantation, ESBL = extended spectrum beta-lactamase, MDRO = multidrug resistant organism, rUTI = recurrent urinary tract infection, FMT = faecal microbiota transplantation, rCDI = recurrent *Clostridioides difficile* infection, AML = acute myeloid leukaemia, NR = not reported, NDM-1 = New Delhi Metallo-beta-lactamase – 1, AB = antibiotics, BL = bowel lavage, PPI = proton pump inhibitor, BSI = bloodstream infection

FMT procedure

The primary route of administration for FMT was upper endoscopy; a minority of studies used capsules, enemas or colonoscopy. Whereas stool volume varied (from 25-100 gram), all stool samples were obtained from healthy, unrelated donors, and were mostly frozen. One study [28] pretreated patients with non-absorbable antibiotics (oral colistin), and in seven studies patients had used antibiotics in the week prior to FMT. [25-27, 29, 30, 32, 34] Patients were pretreated with PPI in seven studies, and bowel lavage in six studies. Moreover, the number of transplantations varied, with six studies performing multiple transplantations per patient.

FMT efficacy: decolonisation and infection rate

In the seven included cohort studies investigating any MDRO, decolonisation rates ranged from 20-90% for patients treated with FMT and 11-66% for controls. Duration of follow-up varied from 1-24 months. The largest between group difference was seen in the prospective cohort study by Lee et al. [23], i.e. a decolonisation rate of 71.4% versus 11.1% for FMT patients and controls respectively. Of note, duration of follow-up was only 3 months, while spontaneous decolonisation usually occurs at a later time point. [9] In the largest study performed thus far [26]**, decolonisation rates were 65.7% (FMT) versus 25.0% (controls) at 6 months, and remained similar at 12 months (68.6% versus 27.1% for FMT patients and controls respectively).

Four of seven cohort studies included both CRE and VRE patients. Of these, two reported decolonisation rates for CRE and VRE patients separately. [23, 26] In the study by Lee et al. [23] CRE decolonisation rate at 3 months was 88.9% (8/9 patients) for the FMT group and 25% (1/4 patients) for the control group. For VRE patients, decolonisation was only reported for 1 month post-FMT, being 60% (3/5 patients) for the FMT group and 0% (number of patients not specified) for the control group. In the study by Seong et al. [26]**, the 12-month decolonisation rate for CRE patients was 75% (3/4 patients) and 45% (9/20 patients) for the FMT and control group respectively. For VRE patients, a 12-month decolonisation rate of 52.6% (10/19 patients) for the FMT group and 12.5% (3/12 patients) for the control group was observed.

In the study by Merli et al. [28] decolonisation was achieved for four out of five paediatric recipients after 1 week, but all four patients were recolonised after 1

month. All patients received antibiotic prophylaxis after a minimum of 3 days post-FMT, as part of the conditioning regimen for allo-SCT. Recolonisation also occurred during antibiotic prophylaxis (for allo-SCT) in an adult patient. [31] Silva et al. [29], Su et al. [33] and Wang et al. [34] were the only studies in which patients did not receive antibiotics after FMT. Prolonged decolonisation was achieved in four out of five CRE patients in the first study, and in both patients in the case reports.

The occurrence of MDRO infections was reported in four out of seven cohort studies. In the two studies with a control group [24, 25], MDRO infections were less frequent in the intervention group. While Bar-Yoseph et al. [24] showed a modest decolonisation rate 6 months post-FMT (66.7%), no MDRO infections occurred in the FMT group. In contrast, 37.5% of patients in the control group experienced MDRO infections. A similar effect was reported by Ghani et al. [25], where only 41% of patients achieved decolonisation, but there was a significant reduction in bloodstream infections (BSI) (no haematology patient developed bacteraemia with their pre-FMT MDRO) and MDRO UTIs (pre-FMT median = 4 ± 2 episodes, post-FMT median = 1 ± 2 episodes), compared to controls.

Microbiota composition pre- and post-FMT

Three case reports [32-34] and two cohort studies [26, 28] reported pre-FMT microbiota composition of patients with MDRO colonisation. Dysbiosis was seen in all patients of the case reports, with Proteobacteria making up more than a third of their gut microbiota, most likely due to prolonged broad-spectrum antimicrobial therapy prior to FMT. Low species richness was also seen in several patients in the study by Merli et al. [28], with one patient having a microbiota profile that was almost exclusively comprised of Enterobacteriaceae (97%). Moreover, Seong et al. [26] showed that patients colonised with VRE had higher counts of Proteobacteria en Verrucomicrobia than healthy stool donors. Seven studies reported faecal microbiota composition after FMT. [24, 26-28, 32-34] Bar-Yoseph [24] showed that post-FMT stool samples of responders, i.e. successfully decolonised patients, resembled those of donors, which was not seen for non-responders. While abundance of Enterobacteriaceae decreased in post-FMT stool samples of responders, it increased for non-responders. After FMT, significantly higher counts of *Bifidobacterium bifidum* were observed in samples of responders, compared to non-responders. Lee et al. [27] showed greater microbiota diversity

post-FMT, with a significantly increased abundance of Bacteroidetes, which was also observed in three case reports. [32-34]

Ongoing trials

Currently, there are 24 ongoing trials investigating FMT for MDRO decolonisation, including 13 RCTs and 11 prospective cohort studies. The largest RCT (NCT04431934) is aiming to enrol 437 patients and is expected to be completed December 2022. Very few studies have posted preliminary results, as shown in **Supplementary Table 1**.

Risk of bias assessment

A summary of the risk of bias assessments for the included cohort studies is presented in **Supplementary Table 2**. Overall, there were concerns about risk of bias for two out of seven cohort studies [23, 25], mainly due to dropouts (without description of those lost), and inadequate descriptions of the study population and outcomes.

Discussion

In this narrative review, we provide an overview of recent studies investigating the efficacy of FMT for MDRO decolonisation. Only a few studies have addressed this question since 2020. In line with earlier reviews on the same topic [16, 17, 35, 36], decolonisation rates varied greatly. Although only two studies reported decolonisation rates for CRE and VRE separately and sample sizes were small, decolonisation rates were higher for CRE patients, with a large effect size compared to controls. To date, only one RCT investigating the efficacy of FMT for MDRO decolonisation has been published. [15] In this study, 39 immunocompetent ESBL-E or CRE carriers were randomised to either no intervention or a 5 day course of oral colistin and neomycin followed by FMT. After 35-48 days, there was no significant difference regarding decolonisation rate between the two groups (41% versus 29% for FMT patients and controls respectively). However, the study was limited by not reaching the calculated sample size, using different routes of administration (nasogastric tube and capsules) and pretreating patients with antibiotics in the intervention arm. Furthermore, control subjects were not treated with antibiotics, further complicating assessment of the true efficacy of FMT.

A previous review by Yoon et al. [16] showed that post-FMT antibiotic use led to lower decolonisation rates. While we could not draw any firm conclusions from our included studies, we did observe that recolonisation and a high number of MDRO infections occurred in patients that had received antibiotics post-FMT. This could be explained by the finding that post-FMT antibiotic use can blunt FMT engraftment, as shown by metagenomic analysis in another study. [24]* Another phenomenon that needs to be taken into consideration when interpreting results is spontaneous decolonisation. A systematic review and meta-analysis by Bar-Yoseph et al. [9] showed that, in health care settings, ESBL-E and CRE colonisation rates spontaneously decreased from 80.2% and 73.9% at 1 month to 35.7% and 34.6% at 12 months respectively. In another systematic review including thirteen studies (n = 1936 patients) 80% of VRE patients were decolonised after 40 weeks, however not all studies confirmed decolonisation with three separate swabs. [37] These findings raise the possibility that decolonisation may be falsely attributed to FMT and underline the necessity of a control group when trying to establish the true efficacy of FMT for MDRO decolonisation. Despite this fact, only four of our included studies had a control group, considerably limiting the evidence included in our review. Notably, only two other controlled studies have been conducted prior to 2020. [15, 38]

Intriguingly, while decolonisation rates in two of the larger included cohort studies were moderate, a major reduction in MDRO infections was observed. [24, 25] In another prospective cohort study assessing the incidence of BSI in rCDI patients treated with either FMT or antibiotics, FMT patients had significantly fewer BSI than patients treated with antibiotics (4% versus 26%). [39] The authors hypothesise that FMT may have aided in increasing colonisation resistance by restoring a disturbed microbiota. This may be accompanied by decreasing intestinal permeability (by treating CDI) and thus preventing translocation of Gram negative bacteria into the bloodstream. Other possible explanations include that FMT can reduce inflammation (and thereby translocation) as is observed in patients with inflammatory bowel disease or graft-versus-host disease, similar to patients in the study by Ghani et al. [25, 40, 41] Lastly, even though FMT might not have eradicated the MDRO from the gut completely, it may have reduced the abundance of *Enterobacteriaceae*, and thereby reduced the likelihood of BSI.

Next to the low number of controlled studies, the evidence included in our review is limited by small samples sizes. Two studies reported dropouts, but did not provide a description of those lost. In addition, most studies defined colonisation

as one positive stool culture (or PCR) or rectal/perianal swab, while colonisation is usually defined as at least two consecutive (positive) samples with the most recent confirmation one week prior to FMT. We chose not to exclude studies that only used one culture or PCR to define colonisation, since this would have significantly reduced the number of eligible studies. Moreover, we observed considerable heterogeneity between studies regarding study population (e.g. including immunocompromised patients), type of pathogens, FMT procedure and post-FMT antibiotic use. Therefore, we need to exercise caution in interpreting the results mentioned in **Table 1**. Since eight studies included immunocompromised patients, one might question the generalisability of the results. Although based on small numbers, the systematic review by Yoon et al. [16] showed higher decolonisation rates for immunocompromised patients, compared to immunocompetent patients. For rCDI, FMT is as effective in immunocompromised patients as in immunocompetent patients. [42] Nevertheless, invasive MDRO infections are a considerable problem in immunocompromised patients, highlighting the importance of researching the role of FMT in this specific population.

Our review process had some methodological limitations. While title/abstract and full-text screening was done by two reviewers independently, data extraction and risk of bias assessment was done by one reviewer. However, a second reviewer was always consulted in case of doubt. In case of missing data, we did not contact study authors. Strengths of our review include our comprehensive search strategy, including many databases, searching for meeting abstracts, and repeating the search before submission of our manuscript.

Future research should include sufficiently powered RCTs with an adequate duration of follow-up to account for spontaneous decolonisation. The protocol for FMT should be standardised with one or more treatments, including the use of different donors to study donor effects. It is possible that different strategies should be applied to CRE and VRE gut eradication. Moreover, more stringent definitions of (de)colonisation should be applied and different pre- and post-treatments and routes of administration should be compared to optimise efficacy. Next to decolonisation, the number of MDRO infections post-FMT should be assessed. As shown in **Supplementary Table 1**, several large RCTs, including both immunocompromised and immunocompetent patients, are currently recruiting. At least one RCT (NCT04188743) is using a more stringent definition of colonisation, requiring at least two positive rectal swabs prior to FMT. The same RCT is comparing the efficacy of donor stool to autologous FMT. Another RCT

(NCT04181112) is pretreating one group with antibiotics, while not pretreating the other group. Different routes of administration are being investigated, though they are not being compared head-to-head within a single upcoming trial.

Conclusion

Since 2020, only a handful of smaller, non-controlled studies investigating the efficacy of FMT for MDRO decolonisation have been published. Although a number of these cohort studies show some effect of FMT for MDRO decolonisation, questions remain regarding the true efficacy of FMT (taking spontaneous decolonisation into account), the optimal route of administration, the role of pre- and post-FMT antibiotic use, and the efficacy in different patient populations. Interestingly, despite modest decolonisation rates, FMT reduced the number of MDRO infections, a finding warranting further exploration.

Acknowledgements

The authors would like to thank J.W. Schoones for his excellent help with constructing our search strategy.

References

1. Global antimicrobial resistance surveillance system (GLASS) report: early implementation. Available at: https://apps.who.int/iris/handle/10665/332081.
2. CDC. Antibiotic Resistance Threats in the United States, 2019. Atlanta, GA: U.S. Department of Health and Human Services, CDC. **2019**.
3. European Centre for Disease Prevention and Control. Antimicrobial resistance in the EU/EEA (EARS-Net) - Annual Epidemiological Report 2019. Stockholm: ECDC. **2020**.
4. Jernigan JA, Hatfield KM, Wolford H, et al. Multidrug-Resistant Bacterial Infections in U.S. Hospitalized Patients, 2012-2017. N Engl J Med **2020**; 382(14): 1309-19.
5. Pop-Vicas A, Mitchell SL, Kandel R, Schreiber R, D'Agata EM. Multidrug-resistant gram-negative bacteria in a long-term care facility: prevalence and risk factors. J Am Geriatr Soc **2008**; 56(7): 1276-80.
6. Pop-Vicas AE, D'Agata EM. The rising influx of multidrug-resistant gram-negative bacilli into a tertiary care hospital. Clin Infect Dis **2005**; 40(12): 1792-8.
7. Bilinski J, Robak K, Peric Z, et al. Impact of Gut Colonization by Antibiotic-Resistant Bacteria on the Outcomes of Allogeneic Hematopoietic Stem Cell Transplantation: A Retrospective, Single-Center Study. Biol Blood Marrow Transplant **2016**; 22(6): 1087-93.
8. Tacconelli E, Mazzaferri F, de Smet AM, et al. ESCMID-EUCIC clinical guidelines on decolonization of multidrug-resistant Gram-negative bacteria carriers. Clin Microbiol Infect **2019**; 25(7): 807-17.
9. Bar-Yoseph H, Hussein K, Braun E, Paul M. Natural history and decolonization strategies for ESBL/carbapenem-resistant Enterobacteriaceae carriage: systematic review and meta-analysis. J Antimicrob Chemother **2016**; 71(10): 2729-39.
10. Terveer EM, Vendrik KE, Ooijevaar RE, et al. Faecal microbiota transplantation for Clostridioides difficile infection: Four years' experience of the Netherlands Donor Feces Bank. United European Gastroenterol J **2020**; 8(10): 1236-47.
11. Millan B, Park H, Hotte N, et al. Fecal Microbial Transplants Reduce Antibiotic-resistant Genes in Patients With Recurrent Clostridium difficile Infection. Clin Infect Dis **2016**; 62(12): 1479-86.
12. Song Y, Garg S, Girotra M, et al. Microbiota dynamics in patients treated with fecal microbiota transplantation for recurrent Clostridium difficile infection. PLoS One **2013**; 8(11): e81330.
13. Korach-Rechtman H, Hreish M, Fried C, et al. Intestinal Dysbiosis in Carriers of Carbapenem-Resistant Enterobacteriaceae. mSphere **2020**; 5(2).
14. Araos R, Montgomery V, Ugalde JA, Snyder GM, D'Agata EMC. Microbial Disruption Indices to Detect Colonization With Multidrug-Resistant Organisms. Infect Control Hosp Epidemiol **2017**; 38(11): 1312-8.
15. Huttner BD, de Lastours V, Wassenberg M, et al. A 5-day course of oral antibiotics followed by faecal transplantation to eradicate carriage of multidrug-resistant Enterobacteriaceae: a randomized clinical trial. Clin Microbiol Infect **2019**; 25(7): 830-8.

16. Yoon YK, Suh JW, Kang EJ, Kim JY. Efficacy and safety of fecal microbiota transplantation for decolonization of intestinal multidrug-resistant microorganism carriage: beyond Clostridioides difficile infection. Ann Med **2019**; 51(7-8): 379-89.

17. Saha S, Tariq R, Tosh PK, Pardi DS, Khanna S. Faecal microbiota transplantation for eradicating carriage of multidrug-resistant organisms: a systematic review. Clin Microbiol Infect **2019**; 25(8): 958-63.

18. Dharmaratne P, Rahman N, Leung A, Ip M. Is there a role of faecal microbiota transplantation in reducing antibiotic resistance burden in gut? A systematic review and Meta-analysis. Ann Med **2021**; 53(1): 662-81.

19. Page MJ, McKenzie JE, Bossuyt PM, et al. The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. BMJ **2021**; 372: n71.

20. https://www.crd.york.ac.uk/prospero Record ID 259623.

21. https://www.ebsco.com/products/research-databases/academic-search-premier.

22. Wells GA, Shea B, O'Connell D, et al. The Newcastle-Ottawa Scale (NOS) for assessing the quality of nonrandomised studies in meta-analyses.

23. Lee JH, Shin JB, Ko WJ, Kwon KS, Kim H, Shin YW. Efficacy and safety of fecal microbiota transplantation on clearance of multi-drug resistance organism in multicomorbid patients: A prospective non-randomized comparison trial. United European Gastroenterology Journal **2020**; 8 (8 SUPPL): 499.

24. Bar-Yoseph H, Carasso S, Shklar S, et al. Oral capsulized Fecal microbiota transplantation for eradication of carbapenemase-producing Enterobacteriaceae colonization with a metagenomic perspective. Clin Infect Dis **2020**.

25. Ghani R, Mullish BH, McDonald JAK, et al. Disease Prevention Not Decolonization: A Model for Fecal Microbiota Transplantation in Patients Colonized With Multidrug-resistant Organisms. Clin Infect Dis **2021**; 72(8): 1444-7.

26. Seong H, Lee SK, Cheon JH, et al. Fecal Microbiota Transplantation for multidrug-resistant organism: Efficacy and Response prediction. J Infect **2020**; 81(5): 719-25.

27. Lee JJ, Yong D, Suk KT, et al. Alteration of Gut Microbiota in Carbapenem-Resistant Enterobacteriaceae Carriers during Fecal Microbiota Transplantation According to Decolonization Periods. Microorganisms **2021**; 9(2).

28. Merli P, Putignani L, Ruggeri A, et al. Decolonization of multi-drug resistant bacteria by fecal microbiota transplantation in five pediatric patients before allogeneic hematopoietic stem cell transplantation: gut microbiota profiling, infectious and clinical outcomes. Haematologica **2020**; 105(11): 2686-90.

29. Silva JC, Ponte A, Mota M, et al. Fecal microbiota transplantation in the intestinal decolonization of carbapenamase-producing enterobacteriaceae. Rev Esp Enferm Dig **2020**; 112(12): 925-8.

30. Biernat MM, Urbaniak-Kujda D, Dybko J, Kapelko-Słowik K, Prajs I, Wróbel T. Fecal microbiota transplantation in the treatment of intestinal steroid-resistant graft-versus-host disease: two case reports and a review of the literature. J Int Med Res **2020**; 48(6): 300060520925693.

31. Bilinski J, Lis K, Tomaszewska A, et al. Eosinophilic gastroenteritis and graft-versus-host disease induced by transmission of Norovirus with fecal microbiota transplant. Transpl Infect Dis **2021**; 23(1): e13386.

32. Keen EC, Tasoff P, Hink T, et al. Microbiome Restoration by RBX2660 Does Not Preclude Recurrence of Multidrug-Resistant Urinary Tract Infection Following Subsequent Antibiotic Exposure: A Case Report. Open Forum Infect Dis **2020**; 7(3): ofaa042.

33. Su F, Luo Y, Yu J, et al. Tandem fecal microbiota transplantation cycles in an allogeneic hematopoietic stem cell transplant recipient targeting carbapenem-resistant Enterobacteriaceae colonization: a case report and literature review. Eur J Med Res **2021**; 26(1): 37.

34. Wang J, Li X, Wu X, et al. Fecal Microbiota Transplantation as an Effective Treatment for Carbapenem-Resistant Klebsiella pneumoniae Infection in a Renal Transplant Patient. Infect Drug Resist **2021**; 14: 1805-11.

35. Feehan A, Garcia-Diaz J. Bacterial, Gut Microbiome-Modifying Therapies to Defend against Multidrug Resistant Organisms. Microorganisms **2020**; 8(2).

36. Amrane S, Lagier JC. Faecal Microbiota Transplantation for antibiotic resistant bacteria decolonization. Human Microbiome Journal **2020**; 16.

37. Shenoy ES, Paras ML, Noubary F, Walensky RP, Hooper DC. Natural history of colonization with methicillin-resistant Staphylococcus aureus (MRSA) and vancomycin-resistant Enterococcus (VRE): a systematic review. BMC Infect Dis **2014**; 14: 177.

38. Saidani N, Lagier JC, Cassir N, et al. Faecal microbiota transplantation shortens the colonisation period and allows re-entry of patients carrying carbapenamase-producing bacteria into medical care facilities. Int J Antimicrob Agents **2019**; 53(4): 355-61.

39. Ianiro G, Murri R, Sciume GD, et al. Incidence of Bloodstream Infections, Length of Hospital Stay, and Survival in Patients With Recurrent Clostridioides difficile Infection Treated With Fecal Microbiota Transplantation or Antibiotics: A Prospective Cohort Study. Ann Intern Med **2019**; 171(10): 695-702.

40. Quraishi MN, Shaheen W, Oo YH, Iqbal TH. Immunological mechanisms underpinning faecal microbiota transplantation for the treatment of inflammatory bowel disease. Clin Exp Immunol **2020**; 199(1): 24-38.

41. van Lier YF, Davids M, Haverkate NJE, et al. Donor fecal microbiota transplantation ameliorates intestinal graft-versus-host disease in allogeneic hematopoietic cell transplant recipients. Sci Transl Med **2020**; 12(556).

42. Shogbesan O, Poudel DR, Victor S, et al. A Systematic Review of the Efficacy and Safety of Fecal Microbiota Transplant for Clostridium difficile Infection in Immunocompromised Patients. Can J Gastroenterol Hepatol **2018**; 2018: 1394379.

Supplement
Search strategy

Databases:

PubMed

http://www.ncbi.nlm.nih.gov/pubmed?otool=leiden

((("Fecal Microbiota Transplantation"[Mesh] OR "fecal microbiota transplantation"[tw] OR "fecal microbiota transplantations"[tw] OR "fecal microbiota transplant"[tw] OR "fecal microbiota transplant*"[tw] OR "fecal microbiota transfer"[tw] OR "fecal microbiota transfer*"[tw] OR "faecal microbiota transplantation"[tw] OR "faecal microbiota transplant"[tw] OR "faecal microbiota transplant*"[tw] OR "faecal microbiota transfer"[tw] OR "faecal microbiota transfer*"[tw] OR "Intestinal Microbiota Transfer"[tw] OR "Intestinal Microbiota Transplantation"[tw] OR "Intestinal Microbiota transplant"[tw] OR "Intestinal Microbiota transplant*"[tw] OR "Donor Feces Infusion"[tw] OR "Donor Feces"[tw] OR "Donor Faeces"[tw] OR "Donor Fecal"[tw] OR "Donor Faecal"[tw] OR "fecal microbial transplantation"[tw] OR "fecal microbial transplant"[tw] OR "fecal microbial transplant*"[tw] OR "fecal microbial transfer"[tw] OR "fecal microbial transfer*"[tw] OR "faecal microbial transplantation"[tw] OR "faecal microbial transplant"[tw] OR "faecal microbial transplant*"[tw] OR "fecal transplantation"[tw] OR "fecal transplant"[tw] OR "fecal transplant*"[tw] OR "fecal transfer"[tw] OR "fecal transfer*"[tw] OR "faecal transplantation"[tw] OR "faecal transplant"[tw] OR "faecal transplant*"[tw] OR "fecal microbiome transplantation"[tw] OR "fecal microbiome transplantations"[tw] OR "fecal microbiome transplant"[tw] OR "fecal microbiome transplant*"[tw] OR "fecal microbiome transfer"[tw] OR "fecal microbiome transfer*"[tw] OR "faecal microbiome transplantation"[tw] OR "faecal microbiome transplant*"[tw] OR (("fecal microbiota"[tw] OR "feces microbiota"[tw] OR "faecal microbiota"[tw] OR "faeces microbiota"[tw] OR "fecal microb*"[tw] OR "feces microb*"[tw] OR "faecal microb*"[tw] OR "faeces microb*"[tw]) AND ("transplant*"[tw]))) AND ("colonization"[tw] OR "colonisation"[tw] OR "decolonization"[tw] OR "decolonisation"[tw] OR "coloniz*"[tw] OR "colonis*"[tw] OR "decoloniz*"[tw] OR "decolonis*"[tw] OR "antibiotic resistance"[tw] OR "Drug Resistance, Microbial"[Mesh] OR "multi-drug resistant"[tw] OR "multi-drug resistance"[tw] OR "multidrug resistant"[tw] OR "multidrug resistance"[tw] OR "carbapenem"[tw] OR "Carbapenems"[Mesh] OR "Carbapenem*"[tw] OR "Doripenem"[tw] OR "Ertapenem"[tw] OR "Thienamycins"[tw] OR "Thienamycin"[tw] OR "Imipenem"[tw] OR "Meropenem"[tw] OR "vancomycin"[tw] OR "Vancomycin"[Mesh] OR "Vancomycin*"[tw] OR "ESBL"[tw] OR "extended spectrum"[tw] OR "extendedspectrum"[tw] OR "extended spectr*"[tw] OR "extendedspectr*"[tw] OR "multi-resistant"[tw] OR "drug resistant"[tw] OR "multi-resistance"[tw] OR "drug resistance"[tw] OR "multi-resistan*"[tw] OR "drug resistan*"[tw]) AND ("2019/01/01"[PDAT] : "3000/12/31"[PDAT]))

Embase

http://ovidsp.ovid.com/ovidweb.cgi?T=JS&PAGE=main&MODE=ovid&D=oemezd

((*"Fecal Microbiota Transplantation"/ OR "fecal microbiota transplantation".ti,ab OR "fecal microbiota transplantations".ti,ab OR "fecal microbiota transplant".ti,ab OR "fecal microbiota transplant*".ti,ab OR "fecal microbiota transfer".ti,ab OR "fecal microbiota transfer*".ti,ab OR "faecal microbiota transplantation".ti,ab OR "faecal microbiota transplant".ti,ab OR "faecal microbiota transplant*".ti,ab OR "faecal microbiota transfer".ti,ab OR "faecal microbiota transfer*".

ti,ab OR "Intestinal Microbiota Transfer".ti,ab OR "Intestinal Microbiota Transplantation".ti,ab OR "Intestinal Microbiota transplant".ti,ab OR "Intestinal Microbiota transplant*".ti,ab OR "Donor Feces Infusion".ti,ab OR "Donor Feces".ti,ab OR "Donor Faeces".ti,ab OR "Donor Fecal".ti,ab OR "Donor Faecal".ti,ab OR "fecal microbial transplantation".ti,ab OR "fecal microbial transplant".ti,ab OR "fecal microbial transplant*".ti,ab OR "fecal microbial transfer".ti,ab OR "fecal microbial transfer*". ti,ab OR "faecal microbial transplantation".ti,ab OR "faecal microbial transplant".ti,ab OR "faecal microbial transplant*".ti,ab OR "fecal transplantation".ti,ab OR "fecal transplant".ti,ab OR "fecal transplant*".ti,ab OR "fecal transfer".ti,ab OR "fecal transfer*".ti,ab OR "faecal transplantation".ti,ab OR "faecal transplant".ti,ab OR "faecal transplant*".ti,ab OR "fecal microbiome transplantation". ti,ab OR "fecal microbiome transplantations".ti,ab OR "fecal microbiome transplant".ti,ab OR "fecal microbiome transplant*".ti,ab OR "fecal microbiome transfer".ti,ab OR "fecal microbiome transfer*".ti,ab OR "faecal microbiome transplantation".ti,ab OR "faecal microbiome transplant*". ti,ab OR (("fecal microbiota".ti,ab OR "feces microbiota".ti,ab OR "faecal microbiota".ti,ab OR "faeces microbiota".ti,ab OR "fecal microb*".ti,ab OR "feces microb*".ti,ab OR "faecal microb*". ti,ab OR "faeces microb*".ti,ab) ADJ6 ("transplant*".ti,ab))) AND (exp *"microbial colonization"/ OR "colonization".ti,ab OR "colonisation".ti,ab OR "decolonization".ti,ab OR "decolonisation".ti,ab OR "coloniz*".ti,ab OR "colonis*".ti,ab OR "decoloniz*".ti,ab OR "decolonis*".ti,ab OR exp *"antibiotic resistance"/ OR "antibiotic resistance".ti,ab OR *"multidrug resistance"/ OR "multi-drug resistant". ti,ab OR "multi-drug resistance".ti,ab OR "multidrug resistant".ti,ab OR "multidrug resistance". ti,ab OR *"carbapenem"/ OR *"carbapenem derivative"/ OR "carbapenem".ti,ab OR "Carbapenem*". ti,ab OR *"Doripenem"/ OR *"Ertapenem"/ OR *"Thienamycins"/ OR *"Thienamycin"/ OR *"Imipenem"/ OR *"Meropenem"/ OR "Doripenem".ti,ab OR "Ertapenem".ti,ab OR "Thienamycins". ti,ab OR "Thienamycin".ti,ab OR "Imipenem".ti,ab OR "Meropenem".ti,ab OR "vancomycin".ti,ab OR *"Vancomycin"/ OR *"Vancomycin derivative"/ OR "Vancomycin*".ti,ab OR *"extended spectrum beta lactamase"/ OR "ESBL".ti,ab OR "extended spectrum".ti,ab OR "extendedspectrum".ti,ab OR "extended spectr*".ti,ab OR "extendedspectr*".ti,ab OR "multi-resistant".ti,ab OR "drug resistant". ti,ab OR "multi-resistance".ti,ab OR "drug resistance".ti,ab OR "multi-resistan*".ti,ab OR "drug resistan*".ti,ab) AND (2019 OR 2020 OR 2021 OR 2022).yr)

NOT conference review.pt
NOT (conference review or conference abstract).pt
AND (conference abstract).pt

Web of Science

http://isiknowledge.com/wos

((ti=("Fecal Microbiota Transplantation" OR "fecal microbiota transplantation" OR "fecal microbiota transplantations" OR "fecal microbiota transplant" OR "fecal microbiota transplant*" OR "fecal microbiota transfer" OR "fecal microbiota transfer*" OR "faecal microbiota transplantation" OR "faecal microbiota transplant" OR "faecal microbiota transplant*" OR "faecal microbiota transfer" OR "faecal microbiota transfer*" OR "Intestinal Microbiota Transfer" OR "Intestinal Microbiota Transplantation" OR "Intestinal Microbiota transplant" OR "Intestinal Microbiota transplant*" OR "Donor Feces Infusion" OR "Donor Feces" OR "Donor Faeces" OR "Donor Fecal" OR "Donor Faecal" OR "fecal microbial transplantation" OR "fecal microbial transplant" OR "fecal microbial transplant*" OR "fecal microbial transfer" OR "fecal microbial transfer*" OR "faecal microbial transplantation" OR "faecal microbial transplant" OR "faecal microbial transplant*" OR "fecal transplantation"

OR "fecal transplant" OR "fecal transplant*" OR "fecal transfer" OR "fecal transfer*" OR "faecal transplantation" OR "faecal transplant" OR "faecal transplant*" OR "fecal microbiome transplantation" OR "fecal microbiome transplantations" OR "fecal microbiome transplant" OR "fecal microbiome transplant*" OR "fecal microbiome transfer" OR "fecal microbiome transfer*" OR "faecal microbiome transplantation" OR "faecal microbiome transplant*" OR (("fecal microbiota" OR "feces microbiota" OR "faecal microbiota" OR "faeces microbiota" OR "fecal microb*" OR "feces microb*" OR "faecal microb*" OR "faeces microb*") AND ("transplant*"))) OR ab=("Fecal Microbiota Transplantation" OR "fecal microbiota transplantation" OR "fecal microbiota transplantations" OR "fecal microbiota transplant" OR "fecal microbiota transplant*" OR "fecal microbiota transfer" OR "fecal microbiota transfer*" OR "faecal microbiota transplantation" OR "faecal microbiota transplant" OR "faecal microbiota transplant*" OR "faecal microbiota transfer" OR "faecal microbiota transfer*" OR "Intestinal Microbiota Transfer" OR "Intestinal Microbiota Transplantation" OR "Intestinal Microbiota transplant" OR "Intestinal Microbiota transplant*" OR "Donor Feces Infusion" OR "Donor Feces" OR "Donor Faeces" OR "Donor Fecal" OR "Donor Faecal" OR "fecal microbial transplantation" OR "fecal microbial transplant" OR "fecal microbial transplant*" OR "fecal microbial transfer" OR "fecal microbial transfer*" OR "faecal microbial transplantation" OR "faecal microbial transplant" OR "faecal microbial transplant*" OR "fecal transplantation" OR "fecal transplant" OR "fecal transplant*" OR "fecal transfer" OR "fecal transfer*" OR "faecal transplantation" OR "faecal transplant" OR "faecal transplant*" OR "fecal microbiome transplantation" OR "fecal microbiome transplantations" OR "fecal microbiome transplant" OR "fecal microbiome transplant*" OR "fecal microbiome transfer" OR "fecal microbiome transfer*" OR "faecal microbiome transplantation" OR "faecal microbiome transplant*" OR (("fecal microbiota" OR "feces microbiota" OR "faecal microbiota" OR "faeces microbiota" OR "fecal microb*" OR "feces microb*" OR "faecal microb*" OR "faeces microb*") NEAR/6 ("transplant*"))) OR ak=("Fecal Microbiota Transplantation" OR "fecal microbiota transplantation" OR "fecal microbiota transplantations" OR "fecal microbiota transplant" OR "fecal microbiota transplant*" OR "fecal microbiota transfer" OR "fecal microbiota transfer*" OR "faecal microbiota transplantation" OR "faecal microbiota transplant" OR "faecal microbiota transplant*" OR "faecal microbiota transfer" OR "faecal microbiota transfer*" OR "Intestinal Microbiota Transfer" OR "Intestinal Microbiota Transplantation" OR "Intestinal Microbiota transplant" OR "Intestinal Microbiota transplant*" OR "Donor Feces Infusion" OR "Donor Feces" OR "Donor Faeces" OR "Donor Fecal" OR "Donor Faecal" OR "fecal microbial transplantation" OR "fecal microbial transplant" OR "fecal microbial transplant*" OR "fecal microbial transfer" OR "fecal microbial transfer*" OR "faecal microbial transplantation" OR "faecal microbial transplant" OR "faecal microbial transplant*" OR "fecal transplantation" OR "fecal transplant" OR "fecal transplant*" OR "fecal transfer" OR "fecal transfer*" OR "faecal transplantation" OR "faecal transplant" OR "faecal transplant*" OR "fecal microbiome transplantation" OR "fecal microbiome transplantations" OR "fecal microbiome transplant" OR "fecal microbiome transplant*" OR "fecal microbiome transfer" OR "fecal microbiome transfer*" OR "faecal microbiome transplantation" OR "faecal microbiome transplant*" OR (("fecal microbiota" OR "feces microbiota" OR "faecal microbiota" OR "faeces microbiota" OR "fecal microb*" OR "feces microb*" OR "faecal microb*" OR "faeces microb*") NEAR/6 ("transplant*")))) AND (ti=("microbial colonization" OR "colonization" OR "colonisation" OR "decolonization" OR "decolonisation" OR "coloniz*" OR "colonis*" OR "decoloniz*" OR "decolonis*" OR "antibiotic resistance" OR "antibiotic resistance" OR "multidrug resistance" OR "multi-drug resistant" OR "multi-drug resistance" OR "multidrug resistant" OR "multidrug resistance" OR "carbapenem" OR "carbapenem derivative" OR "carbapenem" OR "Carbapenem*" OR "Doripenem" OR "Ertapenem" OR "Thienamycins" OR "Thienamycin" OR "Imipenem" OR

"Meropenem" OR "Doripenem" OR "Ertapenem" OR "Thienamycins" OR "Thienamycin" OR "Imipenem" OR "Meropenem" OR "vancomycin" OR "Vancomycin" OR "Vancomycin derivative" OR "Vancomycin*" OR "extended spectrum beta lactamase" OR "ESBL" OR "extended spectrum" OR "extendedspectrum" OR "extended spectr*" OR "extendedspectr*" OR "multi-resistant" OR "drug resistant" OR "multi-resistance" OR "drug resistance" OR "multi-resistan*" OR "drug resistan*") OR ab=("microbial colonization" OR "colonization" OR "colonisation" OR "decolonization" OR "decolonisation" OR "coloniz*" OR "colonis*" OR "decoloniz*" OR "decolonis*" OR "antibiotic resistance" OR "antibiotic resistance" OR "multidrug resistance" OR "multi-drug resistant" OR "multi-drug resistance" OR "multidrug resistant" OR "multidrug resistance" OR "carbapenem" OR "carbapenem derivative" OR "carbapenem" OR "Carbapenem*" OR "Doripenem" OR "Ertapenem" OR "Thienamycins" OR "Thienamycin" OR "Imipenem" OR "Meropenem" OR "Doripenem" OR "Ertapenem" OR "Thienamycins" OR "Thienamycin" OR "Imipenem" OR "Meropenem" OR "vancomycin" OR "Vancomycin" OR "Vancomycin derivative" OR "Vancomycin*" OR "extended spectrum beta lactamase" OR "ESBL" OR "extended spectrum" OR "extendedspectrum" OR "extended spectr*" OR "extendedspectr*" OR "multi-resistant" OR "drug resistant" OR "multi-resistance" OR "drug resistance" OR "multi-resistan*" OR "drug resistan*") OR ak=("microbial colonization" OR "colonization" OR "colonisation" OR "decolonization" OR "decolonisation" OR "coloniz*" OR "colonis*" OR "decoloniz*" OR "decolonis*" OR "antibiotic resistance" OR "antibiotic resistance" OR "multidrug resistance" OR "multi-drug resistant" OR "multi-drug resistance" OR "multidrug resistant" OR "multidrug resistance" OR "carbapenem" OR "carbapenem derivative" OR "carbapenem" OR "Carbapenem*" OR "Doripenem" OR "Ertapenem" OR "Thienamycins" OR "Thienamycin" OR "Imipenem" OR "Meropenem" OR "Doripenem" OR "Ertapenem" OR "Thienamycins" OR "Thienamycin" OR "Imipenem" OR "Meropenem" OR "vancomycin" OR "Vancomycin" OR "Vancomycin derivative" OR "Vancomycin*" OR "extended spectrum beta lactamase" OR "ESBL" OR "extended spectrum" OR "extendedspectrum" OR "extended spectr*" OR "extendedspectr*" OR "multi-resistant" OR "drug resistant" OR "multi-resistance" OR "drug resistance" OR "multi-resistan*" OR "drug resistan*")) AND py=(2019 OR 2020 OR 2021 OR 2022))

Cochrane

https://www.cochranelibrary.com/advanced-search/search-manager

(("Fecal Microbiota Transplantation" OR "fecal microbiota transplantation" OR "fecal microbiota transplantations" OR "fecal microbiota transplant" OR "fecal microbiota transplant*" OR "fecal microbiota transfer" OR "fecal microbiota transfer*" OR "faecal microbiota transplantation" OR "faecal microbiota transplant" OR "faecal microbiota transplant*" OR "faecal microbiota transfer" OR "faecal microbiota transfer*" OR "Intestinal Microbiota Transfer" OR "Intestinal Microbiota Transplantation" OR "Intestinal Microbiota transplant" OR "Intestinal Microbiota transplant*" OR "Donor Feces Infusion" OR "Donor Feces" OR "Donor Faeces" OR "Donor Fecal" OR "Donor Faecal" OR "fecal microbial transplantation" OR "fecal microbial transplant" OR "fecal microbial transplant*" OR "fecal microbial transfer" OR "fecal microbial transfer*" OR "faecal microbial transplantation" OR "faecal microbial transplant" OR "faecal microbial transplant*" OR "fecal transplantation" OR "fecal transplant" OR "fecal transplant*" OR "fecal transfer" OR "fecal transfer*" OR "faecal transplantation" OR "faecal transplant" OR "faecal transplant*" OR "fecal microbiome transplantation" OR "fecal microbiome transplantations" OR "fecal microbiome transplant" OR "fecal microbiome transplant*" OR "fecal microbiome transfer" OR "fecal microbiome transfer*"

OR "faecal microbiome transplantation" OR "faecal microbiome transplant*" OR (("fecal microbiota" OR "feces microbiota" OR "faecal microbiota" OR "faeces microbiota" OR "fecal microb*" OR "feces microb*" OR "faecal microb*" OR "faeces microb*") AND ("transplant*"))) AND ("microbial colonization" OR "colonization" OR "colonisation" OR "decolonization" OR "decolonisation" OR "coloniz*" OR "colonis*" OR "decoloniz*" OR "decolonis*" OR "antibiotic resistance" OR "antibiotic resistance" OR "multidrug resistance" OR "multi drug resistant" OR "multi drug resistance" OR "multidrug resistant" OR "multidrug resistance" OR "carbapenem" OR "carbapenem derivative" OR "carbapenem" OR "Carbapenem*" OR "Doripenem" OR "Ertapenem" OR "Thienamycins" OR "Thienamycin" OR "Imipenem" OR "Meropenem" OR "Doripenem" OR "Ertapenem" OR "Thienamycins" OR "Thienamycin" OR "Imipenem" OR "Meropenem" OR "vancomycin" OR "Vancomycin" OR "Vancomycin derivative" OR "Vancomycin*" OR "extended spectrum beta lactamase" OR "ESBL" OR "extended spectrum" OR "extendedspectrum" OR "extended spectr*" OR "extendedspectr*" OR "multi-resistant" OR "drug resistant" OR "multi-resistance" OR "drug resistance" OR "multi-resistan*" OR "drug resistan*")):ti,ab,kw

AND py=(2019 OR 2020 OR 2021 OR 2022)

Emcare

http://ovidsp.ovid.com/ovidweb.cgi?T=JS&NEWS=n&CSC=Y&PAGE=main&D=emcr

((*"Fecal Microbiota Transplantation"/ OR "fecal microbiota transplantation".ti,ab OR "fecal microbiota transplantations".ti,ab OR "fecal microbiota transplant".ti,ab OR "fecal microbiota transplant*".ti,ab OR "fecal microbiota transfer".ti,ab OR "fecal microbiota transfer*".ti,ab OR "faecal microbiota transplantation".ti,ab OR "faecal microbiota transplant".ti,ab OR "faecal microbiota transplant*".ti,ab OR "faecal microbiota transfer".ti,ab OR "faecal microbiota transfer*". ti,ab OR "Intestinal Microbiota Transfer".ti,ab OR "Intestinal Microbiota Transplantation".ti,ab OR "Intestinal Microbiota transplant".ti,ab OR "Intestinal Microbiota transplant*".ti,ab OR "Donor Feces Infusion".ti,ab OR "Donor Feces".ti,ab OR "Donor Faeces".ti,ab OR "Donor Fecal".ti,ab OR "Donor Faecal".ti,ab OR "fecal microbial transplantation".ti,ab OR "fecal microbial transplant".ti,ab OR "fecal microbial transplant*".ti,ab OR "fecal microbial transfer".ti,ab OR "fecal microbial transfer*". ti,ab OR "faecal microbial transplantation".ti,ab OR "faecal microbial transplant".ti,ab OR "faecal microbial transplant*".ti,ab OR "fecal transplantation".ti,ab OR "fecal transplant".ti,ab OR "fecal transplant*".ti,ab OR "fecal transfer".ti,ab OR "fecal transfer*".ti,ab OR "faecal transplantation".ti,ab OR "faecal transplant".ti,ab OR "faecal transplant*".ti,ab OR "fecal microbiome transplantation". ti,ab OR "fecal microbiome transplantations".ti,ab OR "fecal microbiome transplant".ti,ab OR "fecal microbiome transplant*".ti,ab OR "fecal microbiome transfer".ti,ab OR "fecal microbiome transfer*".ti,ab OR "faecal microbiome transplantation".ti,ab OR "faecal microbiome transplant*". ti,ab OR (("fecal microbiota".ti,ab OR "feces microbiota".ti,ab OR "faecal microbiota".ti,ab OR "faeces microbiota".ti,ab OR "fecal microb*".ti,ab OR "feces microb*".ti,ab OR "faecal microb*". ti,ab OR "faeces microb*".ti,ab) ADJ6 ("transplant*".ti,ab))) AND (exp *"microbial colonization"/ OR "colonization".ti,ab OR "colonisation".ti,ab OR "decolonization".ti,ab OR "decolonisation".ti,ab OR "coloniz*".ti,ab OR "colonis*".ti,ab OR "decoloniz*".ti,ab OR "decolonis*".ti,ab OR exp *"antibiotic resistance"/ OR "antibiotic resistance".ti,ab OR *"multidrug resistance"/ OR "multi-drug resistant". ti,ab OR "multi-drug resistance".ti,ab OR "multidrug resistant".ti,ab OR "multidrug resistance". ti,ab OR *"carbapenem"/ OR *"carbapenem derivative"/ OR "carbapenem".ti,ab OR "Carbapenem*". ti,ab OR *"Doripenem"/ OR *"Ertapenem"/ OR *"Thienamycins"/ OR *"Thienamycin"/ OR

*"Imipenem"/ OR *"Meropenem"/ OR "Doripenem".ti,ab OR "Ertapenem".ti,ab OR "Thienamycins".ti,ab OR "Thienamycin".ti,ab OR "Imipenem".ti,ab OR "Meropenem".ti,ab OR "vancomycin".ti,ab OR *"Vancomycin"/ OR *"Vancomycin derivative"/ OR "Vancomycin*".ti,ab OR *"extended spectrum beta lactamase"/ OR "ESBL".ti,ab OR "extended spectrum".ti,ab OR "extendedspectrum".ti,ab OR "extended spectr*".ti,ab OR "extendedspectr*".ti,ab OR "multi-resistant".ti,ab OR "drug resistant".ti,ab OR "multi-resistance".ti,ab OR "drug resistance".ti,ab OR "multi-resistan*".ti,ab OR "drug resistan*".ti,ab) AND (2019 OR 2020 OR 2021 OR 2022).yr)

Academic Search Premier

http://search.ebscohost.com/login.aspx?authtype=ip,uid&profile=lumc&defaultdb=aph

TI(("Fecal Microbiota Transplantation" OR "fecal microbiota transplantation" OR "fecal microbiota transplantations" OR "fecal microbiota transplant" OR "fecal microbiota transplant*" OR "fecal microbiota transfer" OR "fecal microbiota transfer*" OR "faecal microbiota transplantation" OR "faecal microbiota transplant" OR "faecal microbiota transplant*" OR "faecal microbiota transfer" OR "faecal microbiota transfer*" OR "Intestinal Microbiota Transfer" OR "Intestinal Microbiota Transplantation" OR "Intestinal Microbiota transplant" OR "Intestinal Microbiota transplant*" OR "Donor Feces Infusion" OR "Donor Feces" OR "Donor Faeces" OR "Donor Fecal" OR "Donor Faecal" OR "fecal microbial transplantation" OR "fecal microbial transplant" OR "fecal microbial transplant*" OR "fecal microbial transfer" OR "fecal microbial transfer*" OR "faecal microbial transplantation" OR "faecal microbial transplant" OR "faecal microbial transplant*" OR "fecal transplantation" OR "fecal transplant" OR "fecal transplant*" OR "fecal transfer" OR "fecal transfer*" OR "faecal transplantation" OR "faecal transplant" OR "faecal transplant*" OR "fecal microbiome transplantation" OR "fecal microbiome transplantations" OR "fecal microbiome transplant" OR "fecal microbiome transplant*" OR "fecal microbiome transfer" OR "fecal microbiome transfer*" OR "faecal microbiome transplantation" OR "faecal microbiome transplant*" OR (("fecal microbiota" OR "feces microbiota" OR "faecal microbiota" OR "faeces microbiota" OR "fecal microb*" OR "feces microb*" OR "faecal microb*" OR "faeces microb*") AND ("transplant*"))) AND ("microbial colonization" OR "colonization" OR "colonisation" OR "decolonization" OR "decolonisation" OR "coloniz*" OR "colonis*" OR "decoloniz*" OR "decolonis*" OR "antibiotic resistance" OR "antibiotic resistance" OR "multidrug resistance" OR "multi drug resistant" OR "multi drug resistance" OR "multidrug resistant" OR "multidrug resistance" OR "carbapenem" OR "carbapenem derivative" OR "carbapenem" OR "Carbapenem*" OR "Doripenem" OR "Ertapenem" OR "Thienamycins" OR "Thienamycin" OR "Imipenem" OR "Meropenem" OR "Doripenem" OR "Ertapenem" OR "Thienamycins" OR "Thienamycin" OR "Imipenem" OR "Meropenem" OR "vancomycin" OR "Vancomycin" OR "Vancomycin derivative" OR "Vancomycin*" OR "extended spectrum beta lactamase" OR "ESBL" OR "extended spectrum" OR "extendedspectrum" OR "extended spectr*" OR "extendedspectr*" OR "multi-resistant" OR "drug resistant" OR "multi-resistance" OR "drug resistance" OR "multi-resistan*" OR "drug resistan*")) OR SU(("Fecal Microbiota Transplantation" OR "fecal microbiota transplantation" OR "fecal microbiota transplantations" OR "fecal microbiota transplant" OR "fecal microbiota transplant*" OR "fecal microbiota transfer" OR "fecal microbiota transfer*" OR "faecal microbiota transplantation" OR "faecal microbiota transplant" OR "faecal microbiota transplant*" OR "faecal microbiota transfer" OR "faecal microbiota transfer*" OR "Intestinal Microbiota Transfer" OR "Intestinal Microbiota Transplantation" OR "Intestinal Microbiota transplant" OR "Intestinal Microbiota transplant*" OR "Donor Feces Infusion" OR "Donor Feces" OR "Donor Faeces" OR "Donor Fecal" OR "Donor Faecal" OR "fecal microbial transplantation"

OR "fecal microbial transplant" OR "fecal microbial transplant*" OR "fecal microbial transfer" OR "fecal microbial transfer*" OR "faecal microbial transplantation" OR "faecal microbial transplant" OR "faecal microbial transplant*" OR "fecal transplantation" OR "fecal transplant" OR "fecal transplant*" OR "fecal transfer" OR "fecal transfer*" OR "faecal transplantation" OR "faecal transplant" OR "faecal transplant*" OR "fecal microbiome transplantation" OR "fecal microbiome transplantations" OR "fecal microbiome transplant" OR "fecal microbiome transplant*" OR "fecal microbiome transfer" OR "fecal microbiome transfer*" OR "faecal microbiome transplantation" OR "faecal microbiome transplant*") AND ("microbial colonization" OR "colonization" OR "colonisation" OR "decolonization" OR "decolonisation" OR "coloniz*" OR "colonis*" OR "decoloniz*" OR "decolonis*" OR "antibiotic resistance" OR "antibiotic resistance" OR "multidrug resistance" OR "multi drug resistant" OR "multi drug resistance" OR "multidrug resistant" OR "multidrug resistance" OR "carbapenem" OR "carbapenem derivative" OR "carbapenem" OR "Carbapenem*" OR "Doripenem" OR "Ertapenem" OR "Thienamycins" OR "Thienamycin" OR "Imipenem" OR "Meropenem" OR "Doripenem" OR "Ertapenem" OR "Thienamycins" OR "Thienamycin" OR "Imipenem" OR "Meropenem" OR "vancomycin" OR "Vancomycin" OR "Vancomycin derivative" OR "Vancomycin*" OR "extended spectrum beta lactamase" OR "ESBL" OR "extended spectrum" OR "extendedspectrum" OR "extended spectr*" OR "extendedspectr*" OR "multi-resistant" OR "drug resistant" OR "multi-resistance" OR "drug resistance" OR "multi-resistan*" OR "drug resistan*")) OR KW(("Fecal Microbiota Transplantation" OR "fecal microbiota transplantation" OR "fecal microbiota transplantations" OR "fecal microbiota transplant" OR "fecal microbiota transplant*" OR "fecal microbiota transfer" OR "fecal microbiota transfer*" OR "faecal microbiota transplantation" OR "faecal microbiota transplant" OR "faecal microbiota transplant*" OR "faecal microbiota transfer" OR "faecal microbiota transfer*" OR "Intestinal Microbiota Transfer" OR "Intestinal Microbiota Transplantation" OR "Intestinal Microbiota transplant" OR "Intestinal Microbiota transplant*" OR "Donor Feces Infusion" OR "Donor Feces" OR "Donor Faeces" OR "Donor Fecal" OR "Donor Faecal" OR "fecal microbial transplantation" OR "fecal microbial transplant" OR "fecal microbial transplant*" OR "fecal microbial transfer" OR "fecal microbial transfer*" OR "faecal microbial transplantation" OR "faecal microbial transplant" OR "faecal microbial transplant*" OR "fecal transplantation" OR "fecal transplant" OR "fecal transplant*" OR "fecal transfer" OR "fecal transfer*" OR "faecal transplantation" OR "faecal transplant" OR "faecal transplant*" OR "fecal microbiome transplantation" OR "fecal microbiome transplantations" OR "fecal microbiome transplant" OR "fecal microbiome transplant*" OR "fecal microbiome transfer" OR "fecal microbiome transfer*" OR "faecal microbiome transplantation" OR "faecal microbiome transplant*") AND ("microbial colonization" OR "colonization" OR "colonisation" OR "decolonization" OR "decolonisation" OR "coloniz*" OR "colonis*" OR "decoloniz*" OR "decolonis*" OR "antibiotic resistance" OR "antibiotic resistance" OR "multidrug resistance" OR "multi drug resistant" OR "multi drug resistance" OR "multidrug resistant" OR "multidrug resistance" OR "carbapenem" OR "carbapenem derivative" OR "carbapenem" OR "Carbapenem*" OR "Doripenem" OR "Ertapenem" OR "Thienamycins" OR "Thienamycin" OR "Imipenem" OR "Meropenem" OR "Doripenem" OR "Ertapenem" OR "Thienamycins" OR "Thienamycin" OR "Imipenem" OR "Meropenem" OR "vancomycin" OR "Vancomycin" OR "Vancomycin derivative" OR "Vancomycin*" OR "extended spectrum beta lactamase" OR "ESBL" OR "extended spectrum" OR "extendedspectrum" OR "extended spectr*" OR "extendedspectr*" OR "multi-resistant" OR "drug resistant" OR "multi-resistance" OR "drug resistance" OR "multi-resistan*" OR "drug resistan*")) OR (TI("Fecal Microbiota Transplantation" OR "fecal microbiota transplantation" OR "fecal microbiota transplantations" OR "fecal microbiota transplant" OR "fecal microbiota transplant*" OR "fecal microbiota transfer" OR

"fecal microbiota transfer*" OR "faecal microbiota transplantation" OR "faecal microbiota transplant" OR "faecal microbiota transplant*" OR "faecal microbiota transfer" OR "faecal microbiota transfer*" OR "Intestinal Microbiota Transfer" OR "Intestinal Microbiota Transplantation" OR "Intestinal Microbiota transplant" OR "Intestinal Microbiota transplant*" OR "Donor Feces Infusion" OR "Donor Feces" OR "Donor Faeces" OR "Donor Fecal" OR "Donor Faecal" OR "fecal microbial transplantation" OR "fecal microbial transplant" OR "fecal microbial transplant*" OR "fecal microbial transfer" OR "fecal microbial transfer*" OR "faecal microbial transplantation" OR "faecal microbial transplant" OR "faecal microbial transplant*" OR "fecal transplantation" OR "fecal transplant" OR "fecal transplant*" OR "fecal transfer" OR "fecal transfer*" OR "faecal transplantation" OR "faecal transplant" OR "faecal transplant*" OR "fecal microbiome transplantation" OR "fecal microbiome transplantations" OR "fecal microbiome transplant" OR "fecal microbiome transplant*" OR "fecal microbiome transfer" OR "fecal microbiome transfer*" OR "faecal microbiome transplantation" OR "faecal microbiome transplant*" OR (("fecal microbiota" OR "feces microbiota" OR "faecal microbiota" OR "faeces microbiota" OR "fecal microb*" OR "feces microb*" OR "faecal microb*" OR "faeces microb*") AND ("transplant*"))) AND AB("microbial colonization" OR "colonization" OR "colonisation" OR "decolonization" OR "decolonisation" OR "coloniz*" OR "colonis*" OR "decoloniz*" OR "decolonis*" OR "antibiotic resistance" OR "antibiotic resistance" OR "multidrug resistance" OR "multi drug resistant" OR "multi drug resistance" OR "multidrug resistant" OR "multidrug resistance" OR "carbapenem" OR "carbapenem derivative" OR "carbapenem" OR "Carbapenem*" OR "Doripenem" OR "Ertapenem" OR "Thienamycins" OR "Thienamycin" OR "Imipenem" OR "Meropenem" OR "Doripenem" OR "Ertapenem" OR "Thienamycins" OR "Thienamycin" OR "Imipenem" OR "Meropenem" OR "vancomycin" OR "Vancomycin" OR "Vancomycin derivative" OR "Vancomycin*" OR "extended spectrum beta lactamase" OR "ESBL" OR "extended spectrum" OR "extendedspectrum" OR "extended spectr*" OR "extendedspectr*" OR "multi-resistant" OR "drug resistant" OR "multi-resistance" OR "drug resistance" OR "multi-resistan*" OR "drug resistan*"))

Supplementary Table 1: Overview of ongoing trials.

NCT/EUCTR number	Study design	Estimated enrolment (n)	Start date	Estimated completion (and preliminary results if posted)	Inclusion criteria	Arms and Interventions	Primary outcome (secondary outcome is mentioned if relevant)
NCT04431934	Randomised, open-label, controlled trial	437	November 2020	December 2022	Adults with documented rectal colonisation with multidrug resistant gram negative bacteria, eligible for routine digestive decolonisation	7 days of non-absorbable antibiotics followed by: **Group 1**: FMT 2 doses, once a week, 14-17 capsules per dose (dose is equivalent to 50 gr of healthy donor stool) **Group 2**: 2 sachets of probiotics every 12 hours for 14 days **Group 3**: no intervention	Decolonisation rate, defined as negative rectal swab, after 60 days
NCT04188743	Randomised, double-blind, controlled trial	150	December 2019	December 2023	Adults with at least two consecutive confirmations of MDRO colonisation in faeces	**Group 1**: allogenic FMT: 50 gr of healthy donor stool, frozen, administered by nasoduodenal tube **Group 2**: autologous FMT: 50 gr of own stool, frozen, administered by nasoduodenal tube **Group 3**: no intervention	Decolonisation rate, defined as three consecutive negative stool cultures in minimal time span of 2 weeks, after 1 month after treatment

Supplementary Table 1: Continued

NCT/EUCTR number	Study design	Estimated enrolment (n)	Start date	Estimated completion (and preliminary results if posted)	Inclusion criteria	Arms and Interventions	Primary outcome (secondary outcome is mentioned if relevant)
NCT04146337	Randomised, open-label, controlled trial	60	October 2020	June 2022	Adult inpatients positive for CRE of any strain and resistance mechanism in rectal surveillance stool samples, with or without CRE clinical samples. A positive rectal swab within one week before randomisation is mandatory.	**Group 1**: FMT, 15 capsules a day for two consecutive days after an eight hour fast **Group 2**: no intervention	Decolonisation rate, defined as three consecutive negative rectal cultures, at 28 days
NCT04760665	Randomised, double-blind, controlled trial	120	April 2021	July 2022	Adult patients colonised with KPC-producing *Klebsiella pneumoniae* (undefined), without an active infection in the month prior to inclusion	**Group 1**: four oral capsules containing healthy donor faeces **Group 2**: four oral placebo capsules	Decolonisation rate (undefined) at 30 days
EUCTR2019-004402-10-FR	Randomised, double-blind, controlled trial	214	Not mentioned	Not mentioned	Adult patients colonised with ESBL-E or CRE, assessed with stool culture, and having suffered from an infection with ESBL-E in the previous 12 months	**Group 1**: FMT capsules (n= 25) for two days in a row **Group 2**: placebo	Decolonisation rate at 30 days, determined by (undefined) culture methods

Supplementary Table 1: Continued

NCT/EUCTR number	Study design	Estimated enrolment (n)	Start date	Estimated completion (and preliminary results if posted)	Inclusion criteria	Arms and Interventions	Primary outcome (secondary outcome is mentioned if relevant)
NCT04746222	Randomised, double-blind, controlled trial	108	July 2021	July 2023	Adults (age ≥ 21) colonisation with CRE, confirmed with at least one positive rectal swab (PCR) taken ≤7 days before randomisation. Antibiotics ceased for at least 48 hours pre-randomisation evaluation.	**Group 1**: single dose of 30 oral capsules containing healthy donor stool **Group 2**: single dose of 30 placebo capsules	Decolonisation rate, defined by negative rectal swab (PCR/ culture), at 12 weeks
NCT04759001	Randomised, double-blind, controlled trial	52	February 2021	February 2023	Adults with CRE colonisation, confirmed by a rectal swab	**Group 1**: FMT by colonoscopy with healthy donor stool **Group 2**: placebo (water) administered through colonoscopy	Decolonisation rate, defined by negative rectal swab, at 4 weeks
NCT04181112	Randomised, open-label, controlled trial	90	November 2019	November 2023	Adult renal transplant recipients, colonised with a multidrug resistant organism (undefined), confirmed by rectal swab or stool culture	**Group 1**: FMT using retention enema **Group 2**: Antibiotic pretreatment (undefined) followed by FMT using retention enema **Group 3**: no intervention	Decolonisation rate, defined by negative culture/PCR at 14 and 30 days post-FMT

Supplementary Table 1: Continued

NCT/EUCTR number	Study design	Estimated enrolment (n)	Start date	Estimated completion (and preliminary results if posted)	Inclusion criteria	Arms and Interventions	Primary outcome (secondary outcome is mentioned if relevant)
NCT03802461	Randomised, open-label, controlled trial	40	March 2019	December 2020 (no published data yet)	Adults with ≥ 1 rectal swab, groin, stool, or urine specimen positive for CRE within the past month	**Group 1**: bowel lavage followed by FMT (50 gr healthy donor stool) administered by enema, given on 3 occasions **Group 2**: no intervention	Decolonisation rate (undefined) after 3 months
EUCTR2019-001618-41	Randomised, participant-blinded, controlled, feasibility trial	80	September 2019	March 2022	Adults with documented gastrointestinal carriage of ESBL-E or CRE (stool sample) in the 21 days prior to consent **and** symptomatic infection with the target organism in the preceding 6 months	**Group 1**: FMT capsules (80 gr of healthy donor faeces per 5 capsules) on three consecutive days. Pretreatment with proton-pump inhibitor **Group 2**: Placebo capsules	To determine the feasibility and acceptability of administering encapsulated FMT to participants colonised with ESBL-E/CPE. This will be used to determine if a substantive trial is feasible. A secondary objective is to provide early evidence of **efficacy** (decolonisation rate by culture/PCR at days 10, 40, 100, and 190)

Supplementary Table 1: Continued

NCT/EUCTR number	Study design	Estimated enrolment (n)	Start date	Estimated completion (and preliminary results if posted)	Inclusion criteria	Arms and Interventions	Primary outcome (secondary outcome is mentioned if relevant)
NCT03063437	Randomised, double-blind, controlled trial	9 currently enrolled	August 2017	February 2019 **Preliminary results:** VRE decolonisation at day 10: 1 out of 4 participants in FMT group, and 1 out of 5 participants in placebo group	Adults colonised with VRE (by stool culture) in the last 14 days	**Group 1**: Single dose of FMT (30 capsules per dose) **Group 2**: Placebo capsules	VRE decolonisation rate (absence of VRE on stool culture) at day 10
NCT02922816	Randomised, open-label, controlled trial	20	December 2016	June 2021 (no published data yet)	Adult renal transplant recipients with a history of MDRO infection	**Group 1**: FMT via enema, healthy donor faeces, 2 cycles of 6 weeks, pretreatment with magnesium citrate **Group 2**: pretreatment like group 1, but no FMT. Participants can cross-over to FMT group after one cycle	Decolonisation rate (rectal swab or stool culture) at day 36

Supplementary Table 1: Continued

NCT/EUCTR number	Study design	Estimated enrolment (n)	Start date	Estimated completion (and preliminary results if posted)	Inclusion criteria	Arms and Interventions	Primary outcome (secondary outcome is mentioned if relevant)
NCT03061097	Randomised, double-blind, controlled trial	4 (of 20 estimated) participants currently enrolled	July 2017	June 2019 **Preliminary results:** 0 out of 4 patients were decolonised 28 days after autologous FMT	Long-term care residents with a history of an infection requiring antimicrobial treatment at the discretion of the treating physician	**Group 1**: Autologous 125 mL FMT (biobanked stool from same patient collected before infection requiring antibiotics) via enema **Group 2**: Placebo FMT	Safety (short-term) at Day 7 defined as NIH Grade ≥2 adverse events. Secondary objective: among patients with MDRO colonisation at day 0: decolonisation rate at day 3, day 7 and day 28
NCT02312986	Prospective cohort study, single-group	20	August 2015	July 2020 **Preliminary results:** Data available for 1 participant: had an MDRO infection at 6 months post FMT	Adults with a history of at least three recurrent infections due to an MDRO; at least two recurrent, severe infections due to MDRO requiring hospitalisation; or at least two recurrent infections due to MDRO for which only antimicrobials with rate limiting toxicities are available AND the MDRO is likely of enteric origin.	FMT (150 mL) via enema, no further information	Incidence of adverse events within 12 months of FMT. Secondary outcome: number of subjects with MDRO infections 30 days, 6 months and 12 months post-FMT

Supplementary Table 1: Continued

NCT/EUCTR number	Study design	Estimated enrolment (n)	Start date	Estimated completion (and preliminary results if posted)	Inclusion criteria	Arms and Interventions	Primary outcome (secondary outcome is mentioned if relevant)
NCT02543866	Prospective cohort study, single group	20	February 2017	September 2024	Children and adolescents with a history at least one infection due to pathogens non-susceptible to ceftriaxone, cefotaxime, or ceftazidime	FMT (50 mL) via nasogastric tube, no further information	Incidence of adverse events within 12 months of FMT. Secondary outcome: number of subjects free from MDRO intestinal colonisation and recurrent MDRO infections 2 days, 2 weeks, 4 weeks, 8 weeks, 6 months, and 12 months post-FMT
NCT03167398	Prospective cohort study, single-group	15	February 2018	December 2019 (no published data yet)	Adult inpatients for CRE of any strain and resistance mechanism in rectal surveillance stool samples, with or without CRE clinical samples. A positive rectal swab within one week before randomisation will be mandatory	Capsulised FMT: 15 capsules a day for two consecutive days. Pretreatment with proton pump inhibitor (and during FMT treatment)	Decolonisation rate, defined by three consecutive negative rectal samples, after 1 month

Supplementary Table 1: Continued

NCT/EUCTR number	Study design	Estimated enrolment (n)	Start date	Estimated completion (and preliminary results if posted)	Inclusion criteria	Arms and Interventions	Primary outcome (secondary outcome is mentioned if relevant)
NCT03367910	Prospective cohort study, single-group	60	February 2018	December 2021	Adults with a history of at least three recurrent infections due to an MDRO; at least two recurrent, severe infections due to MDRO requiring hospitalisation; or at least two recurrent infections due to MDRO for which only antimicrobials with rate limiting toxicities are available	FMT (150 mL) via enema, no further information	Incidence of adverse events within 6 months of FMT. Secondary outcome: risk of recurrent UTI 6 months post-FMT and MDRO decolonisation (stool and urine specimens) 6 months post-FMT
NCT03029078	Prospective cohort study, single-group	50	November 2014	January 2024	Adults patients colonised with VRE or CRE, confirmed by at least three positive swabs in the last month	FMT via nasoduodenal tube with healthy donor faeces. Pretreatment with bowel lavage	Decolonisation rate (undefined) at 1 week, 2 weeks, 1 month and 6 months
NCT03479710	Prospective cohort study, with control group, non-randomised, open-label	40	February 2018	December 2021	Adult patients colonised with VRE or CRE, confirmed by two or more stool or rectal swabs at least one week apart	**Group 1**: FMT (100-200 mL) via nasoduodenal tube, with frozen donor stool **Group 2**: no intervention	Decolonisation rate (undefined) at 2 weeks and 12 months
NCT04583098	Prospective cohort study, single-group	100	March 2019	March 2022	Adults colonised with VRE or CRE (undefined)	FMT (route of administration not mentioned) with frozen stool from healthy donors	Decolonisation rate, confirmed by 3 negative rectal swab cultures with a 3 day interval, at 3 months post-FMT

Supplementary Table 1: Continued

NCT/EUCTR number	Study design	Estimated enrolment (n)	Start date	Estimated completion (and preliminary results if posted)	Inclusion criteria	Arms and Interventions	Primary outcome (secondary outcome is mentioned if relevant)
NCT04593368	Prospective cohort study, single-group	15	December 2020	September 2023	Children and adults (aged 3-25) with an indication for allogeneic haematopoietic stem cell transplantation and colonisation with VRE, ESBL-E, *Acinetobacter* spp., MRSA, *Stenotrophomonas* spp., *S. viridans*, *C. difficile* or *Pseudomonas aeruginosa*	FMT (oral, exact route of administration not mentioned) from allogeneic donor, 0.5-2 g/kg of recipients weight	Decolonisation rate (undefined) 7 days after FMT
NCT04790565	Prospective cohort study, single-group	60	April 2021	April 2023	Adults with CRE colonisation in surveillance stool samples, with or without clinical CRE samples	FMT, 15 capsules a day for two consecutive days after an eight hour fast	Decolonisation rate, defined as 3 consecutive negative rectal cultures, at 28 days
NCT03834051	Prospective cohort study, single-group	50	February 2019	August 2020 (no published data yet)	Adults with ESBL-E, CRE or VRE colonisation (undefined)	FMT via enema, no further information	Decolonisation rate, time frame: 2 years

Supplementary Table 1: Continued

NCT/EUCTR number	Study design	Estimated enrolment (n)	Start date	Estimated completion (and preliminary results if posted)	Inclusion criteria	Arms and Interventions	Primary outcome (secondary outcome is mentioned if relevant)
NCT03050515	Prospective cohort study, single-group	12	February 2018	February 2020 (no published data yet)	Female patients (aged > 18) with recurrent urinary tract infections (2 or more culture proven in last 6 months) failing with oral prophylaxis or intravesical instillations with dimethylsulfoxide or heparin/lidocaine	FMT via enema with donor stool, pretreatment with bowel lavage	Change in frequency of culture proven urinary tract infections at 6 months post-FMT

Abbreviations: FMT = faecal microbiota transplantation, MDRO = multidrug resistant organism, CRE = carbapenemase resistant Enterobacteriaceae, KPC = *Klebsiella pneumoniae* carbapenemase, ESBL-E = extended spectrum beta-lactamase producing Enterobacteriaceae, PCR = polymerase chain reaction, VRE = vancomycin resistant *Enterococcus*, MRSA = methicillin resistant *Staphylococcus aureus*

Supplementary Table 2: Risk of bias assessment.

First author & year	Representativeness of exposed cohort	Selection of the non-exposed cohort	Ascertainment of exposure	Demonstration that outcome of interest was not present at start of study	Comparability of cohorts on the basis of the design or analysis	Assessment of outcome	Follow-up long enough for outcome to occur	Adequacy of follow-up
Lee 2020 Korea (25)	**High risk of bias** Characteristics of exposed cohort not described	**High risk of bias** Characteristics of non-exposed cohort not described	**High risk of bias** Not adequately described	**Low risk of bias**	**High risk of bias** Comparability of cohorts could not be assessed because cohorts were not described	**High risk of bias** Assessment of outcome not reported	**Low risk of bias**	**High risk of bias** Many patients lost to follow-up and no description of those lost
Bar-Yoseph 2020 Israel (26)	**Low risk of bias**	**Low risk of bias**	**Low risk of bias**	**Low risk of bias**	**High risk of bias** Significantly more patients in control group had systemic antibiotics and prolonged hospital stay post-FMT.	**Low risk of bias**	**Low risk of bias**	**Low risk of bias**
Ghani 2020 United Kingdom (23)	**High risk of bias** Mostly immunocompromised patients and significant antibiotic use pre- and post-FMT	**Low risk of bias**	**Low risk of bias**	**Low risk of bias**	**Low risk of bias**	**High risk of bias** Not reported for three patients in group 1 and 2, not reported for control group at all	**Low risk of bias**	**High risk of bias** Some dropouts, but no description provided

Supplementary Table 2: Continued

First author & year	Representativeness of exposed cohort	Selection of the non-exposed cohort	Ascertainment of exposure	Demonstration that outcome of interest was not present at start of study	Comparability of cohorts on the basis of the design or analysis	Assessment of outcome	Follow-up long enough for outcome to occur	Adequacy of follow-up
Seong 2020 Korea (24)	**High risk of bias** Significant antibiotic use pre- and post-FMT	**Low risk of bias**	**Low risk of bias**	**Low risk of bias**	**Low risk of bias**	**Low risk of bias**	**Low risk of bias**	**Low risk of bias**
Lee 2020 Korea (28)	**High risk of bias** Inclusion of some rCDI patients	**Not applicable**	**Low risk of bias**	**Low risk of bias**	**Not applicable**	**Low risk of bias**	**Low risk of bias**	**Low risk of bias**
Merli 2020 Italy (29)	**High risk of bias** Exclusively immunocompromised children	**Not applicable**	**Low risk of bias**	**Low risk of bias**	**Not applicable**	**Low risk of bias**	**Low risk of bias**	**Low risk of bias**
Silva 2020 Portugal (27)	**High risk of bias** Concurrent rCDI	**Not applicable**	**Low risk of bias**	**Low risk of bias**	**Not applicable**	**Low risk of bias**	**Low risk of bias**	**Low risk of bias**

Abbreviations: FMT = faecal microbiota transplant, rCDI = recurrent *Clostridioides difficile* infection