JGH Open An open access journal of gastroenterology and hepatology
Open Access
JGHF Journal of Gastroenterology and Hepatology Foundation
doi:10.1002/jgh3.12979

ORIGINAL ARTICLE

Assuring safety of fecal microbiota transplantation in the COVID-19 era: A single-center experience

Tien-En Chang,*,†,‡ Kuei-Chuan Lee,*,‡ Pei-Chang Lee,*,‡ Yen-Po Wang,*,†,‡ Yi-Tsung Lin,‡,§ Hui-Chun Huang,*,‡,¶ Jiing-Chyuan Luo,*,‡,‖ Hsiang-Ling Ho,** Yi-Hsiang Huang*,‡ and Ming-Chih Hou,*,‡ Task Force for Precision Medicine in Gut Microbial Therapy

*Division of Gastroenterology and Hepatology, †Endoscopic Center for Diagnosis and Therapy, §Division of Infectious Diseases, ¶Division of General Medicine, Department of Medicine, ‖Healthcare and Services Center, **Department of Pathology and Laboratory Medicine, Taipei Veterans General Hospital and ‡School of Medicine, College of Medicine, National Yang Ming Chiao Tung University, Taipei, Taiwan

Key words
COVID-19, donor screening, fecal microbiota transplantation, multidrug-resistant organism, SARS-CoV-2.

Accepted for publication 28 September 2023.

Correspondence
Dr Kuei-Chuan Lee and Dr Ming-Chih Hou, Division of Gastroenterology and Hepatology, Department of Medicine, Taipei Veterans General Hospital, No. 201, Shih-Pai Road, Section 2, Taipei 11217, Taiwan.
Email: kclee2@vghtpe.gov.tw and mchou@vghtpe.gov.tw

Declaration of conflict of interest: The authors have stated that there are no conflicts of interest related to this study.
Financial support: This study was funded by the grants from Taipei Veterans General Hospital (V112B-038, V110E-002-2, V111E-003-2, V112E-005-3).

Funding support: Taipei Veterans General Hospital V110E-002-2, V111E-003-2, V112B-038, V112E-005-3

Abstract

Background and Aim: Fecal microbiota transplantation (FMT) is used to treat recurrent or refractory *Clostridioides difficile* infection (CDI). In the past, screening of fecal donors required surveillance of personal behavior, medical history, and diseases that could be transmitted by the blood or fecal–oral route. In addition, the exclusion of multidrug-resistant organisms (MDROs) has been recommended since 2018. This task has become more complicated in the era of the coronavirus disease-2019 (COVID-19) pandemic. To prevent fecal transmission of severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), it is crucial to commence screening for SARS-CoV-2, alongside other traditional tests. Our aim was to investigate whether hidden carriers of SARS-CoV-2 were enrolled for stool donation, and the status of the presence or incidence of MDRO during fecal donation in Taiwan.
Methods: Fecal products collected from March 2019 to December 2022 were tested for MDRO and nucleic acid amplification tests for SARS-CoV-2 using the pooling method. The period of fecal product collection crossed the time before and during the COVID pandemic in Taiwan.
Results: A total of 151 fecal samples were collected. The fecal products were tested using polymerase chain reaction (PCR) to detect SARS-CoV-2. The results were negative for all stocks. This was similar to the results of MDRO testing. The safety of FMT products has been guaranteed during the pandemic.
Conclusion: Our FMT center produced MDRO-free and COVID-19-free products before and during the COVID-19 outbreak in Taiwan. Our protocol was effective for ensuring the safety of FMT products.

Introduction

Fecal microbiota transplantation (FMT) is an effective treatment for recurrent or refractory *Clostridioides difficile* infection (CDI). The first successful randomized controlled trial was published in 2013.[1] This concept has been accepted and implemented by gastroenterologists worldwide.[2] The donors should undergo strict screening, including personal behavior, travel history, blood tests for infectious diseases, and stool tests for pathogens.[2,3] In 2019, two immunocompromised patients who received FMT were infected with extended-spectrum beta-lactamase (ESBL)-producing *Escherichia coli*.[4] Because of concern of multidrug-resistant organisms (MDROs) via FMT, screening of MDROs for stool products was also recommended by the Food and Drug Administration (FDA) in June 2019.[5] Furthermore, after the outbreak of coronavirus disease 2019 (COVID-19), evidence showed that the virus could be secreted into the stool and persistently could exist in the rectal swab even after the nasopharyngeal swab became negative.[6] Therefore, screening for severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) among donors and their products has been recommended since May 2020[7–9] (Fig. 1).

In Taiwan, FMT was approved as a treatment for recurrent of refractory CDI by the Ministry of Health and Welfare in September 2018. We then established a stool bank in our institute in March 2019. We not only followed the recommendations of international consensus in donor selection[2,3] but also screened for MDRO carriers in our protocol from the early era of stool bank establishment, which was before the FDA recommendation.

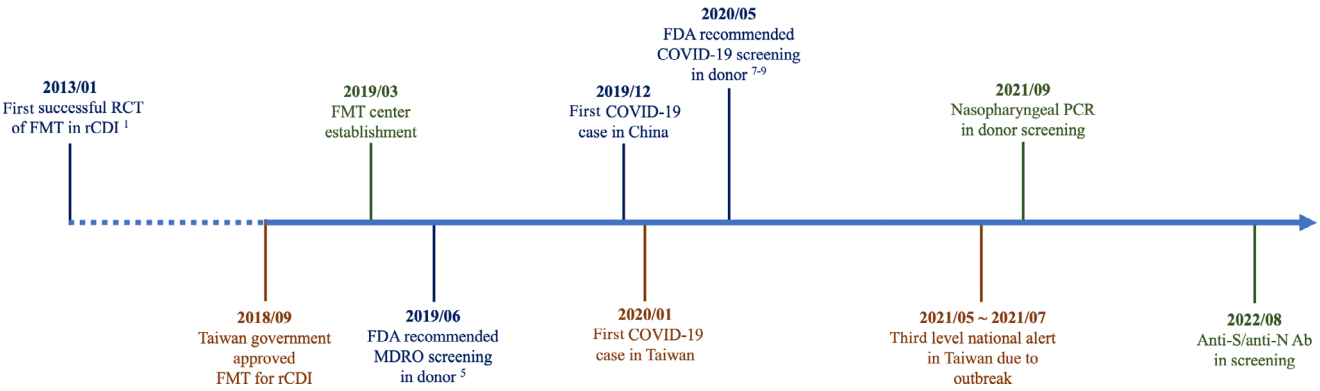

Figure 1 Timeline for fecal microbiota transplantation (FMT) center development. Anti-N/anti-S Ab, spike (S) or nucleocapsid (N) proteins; COVID-19, coronavirus disease-2019; MDRO, multidrug-resistant organism; PCR, polymerase chain reaction; rCDI, recurrent/refractory *Clostridioides difficile* infection; RCT, randomized controlled trial.

Products were discarded or placed under quarantine if MDRO was detected in the following donations (Fig. 1).

The local outbreak of COVID-19 occurred only until May 2021, owing to the strict quarantine policy of Taiwan's governors. Therefore, we did not routinely check for SARS-CoV-2 among donors before stool collection in May 2021. The collection of fecal products was postponed from May 2021 to August 2021 because of rigorous access control in medical institutions under the nationwide level-3 alert for COVID-19. Owing to the raging risk of community infection in the local population and the responsibility of ensuring the safety of products in our center, we started to include SARS-CoV-2 in the donor screening protocol in September 2021. However, the safety of fecal products collected before May 2021 may not be fully guaranteed.

A routine screening program was conducted before the COVID-19 outbreak in our community.[10] After the outbreak of COVID-19 in our community in May 2021, we screened for SARS-CoV-2. Therefore, the aim of this study was to investigate whether hidden carriers of SARS-CoV-2 or MDROs participated in stool donation.

Methods

All fecal products were collected from healthy donors who underwent strict screening. The protocol included questionnaires and clinical assessment on age, body mass index, travel and contact history, high-risk behaviors, and a thorough review of gastrointestinal comorbidities and chronic diseases that may alter the gut microbiome.[2,3,10–16] Individuals who passed the clinical assessment would undergo serologic tests for biochemical profiles and infectious diseases, as well as tests for gastrointestinal pathogens.[2,3,10–16] We collected additional stocks for further analysis, including MDRO testing and SARS-CoV-2 screening, from each fecal product during collection.

Screening for MDROs. All fecal products were tested for pathogens and MDROs after collection at the FMT center. MDROs were defined as microorganisms resistant to at least one agent in three or more antimicrobial categories, including methicillin-resistant *Staphylococcus aureus* (MRSA), vancomycin-resistant enterococci (VRE), and multidrug-resistant gram-negative (MDRGN) bacilli.[17] Patients with MDROs detected in fecal specimens were considered fecal carriers of MDROs. In addition to stool routines and stool culture for *C. difficile* and *Helicobacter pylori* stool antigen test, stool pathogens were also examined by the BIOFIRE FILMARRAY Gastrointestinal Panel. This panel included 22 pathogens, including *C. difficile*, *Salmonella*, *Campylobacter*, *E. coliO157*, enteroaggregative *E. coli* (EAEC), enteropathogenic *E. coli* (EPEC), *Norovirus*, *Rotavirus*, and parasites. MDROs were examined using stool cultures, including carbapenem-resistant *Enterobacteriaceae* (CRE), extended-spectrum beta-lactamase (ESBL), VRE, MRSA, and *Listeria*. Furthermore, to detect MDROs carriage (MRSA, VRE, and MDRGN) in each fecal donation, stool samples were obtained using the Fisherbrand Commode Specimen Collection System and inoculated onto selective agar plates at 37°C for 24 h. MDROs were identified using matrix-assisted laser desorption-ionization time-of-flight mass spectrometry (bioMérieux SA, Marcy l'Etoile, France). Antibiotic susceptibility tests were performed using the VITEK2 system (bioMérieux), and the results were interpreted according to the 2020 Clinical and Laboratory Standards Institute (CLSI) guidelines.[18] Stool polymerase chain reaction (PCR) quantification of *C. difficile* was also performed for each donation. To qualify for fecal transplantation, the products must be negative in the above-mentioned assessments; otherwise, they are discarded.

Screening for SARS-CoV-2. For SARS-CoV-2 screening, a questionnaire was used to exclude individuals with suspicious symptoms, travel, or contact history in the first step. Serial tests, including nasopharyngeal swabs, stool tests, and blood tests, were performed.[7,8,19] Stool donations were approved after the donor passed all screening tests. The donors underwent SARS-CoV-2 rapid antigen tests before each donation. The products were quarantined in the first month after donation. The stool products were sent for pooling nucleic acid amplification tests during quarantine.[20–23] The pooling method allowed researchers to examine multiple samples simultaneously without decreasing the sensitivity of the test.[21] Blood test for anti-spike (S) and anti-nucleocapsid (N) antibodies were added to the screening protocol in August 2022 (Fig. 2). Products

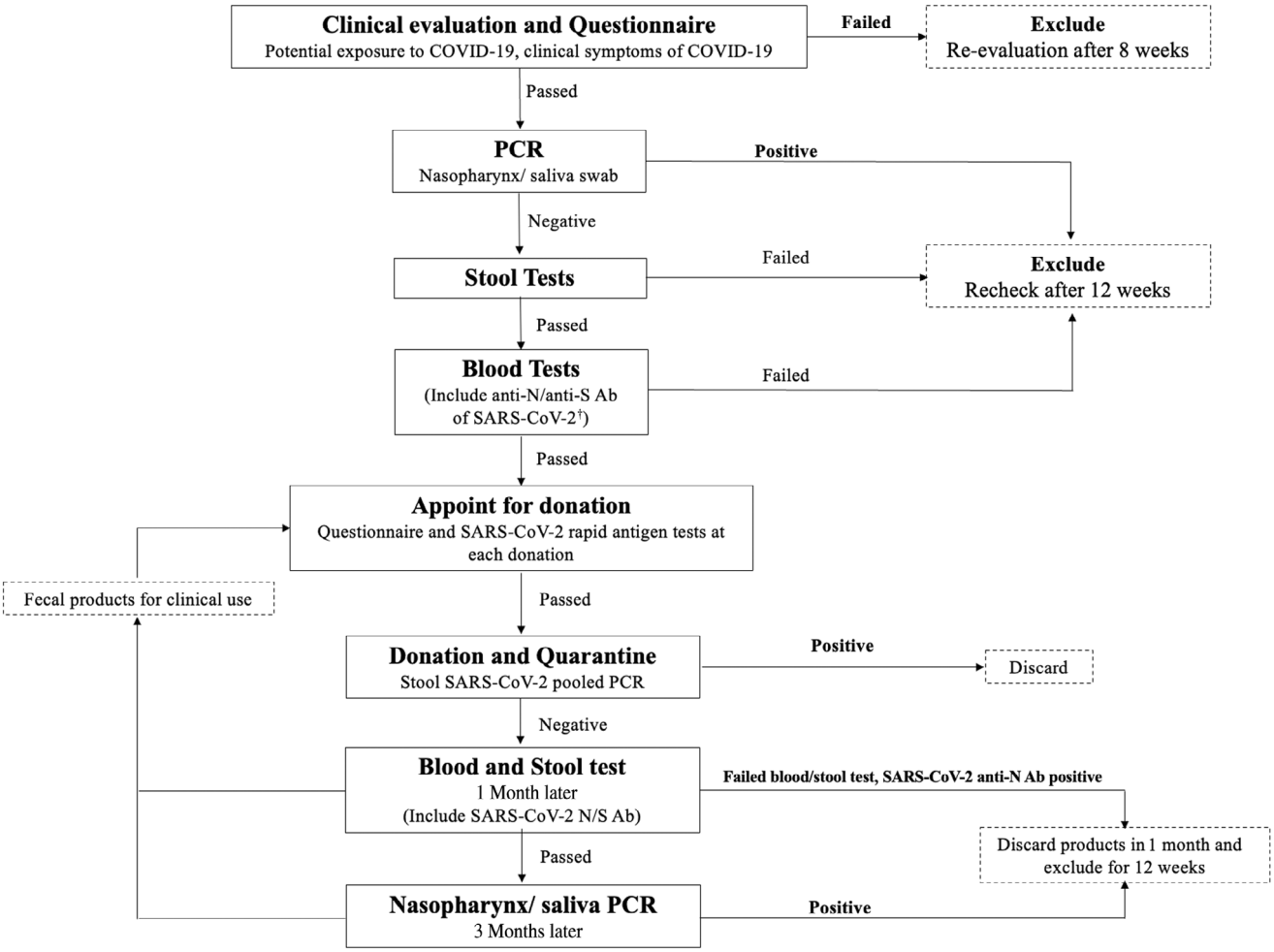

Figure 2 Protocol for coronavirus disease-2019 (COVID-19) screening in our hospital. †Screening for anti-N/anti-S Ab of severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) was started after August 2022. Anti-N/anti-S Ab, spike (S) or nucleocapsid (N) proteins; PCR, polymerase chain reaction.

were allowed for use only if the donor passed SARS-CoV-2 detection and MDRO evaluation in the following donation.

As for stool products that were collected before the screening protocol of SARS-CoV-2 was established in September 2021, nucleic acid amplification was performed immediately to detect SARS-CoV-2 hidden carrier retrospectively (Fig. 3).[21,22] The fecal stocks collected during stool donation were used for the analysis. For pooling method PCR, five samples were pooled together into a total volume of 400 μL and mixed with 400 μL MagNA Pure 96 External Lysis Buffer for the inactivation of the viral particles. The mixtures were centrifuged and injected into the Roche Cobas 6800 system for dual-target real time-PCR. The assay targeted the open reading frames (ORFs) 1a/b and E genes. The results were considered positive if ORF1a/b and E or only ORF1a/b expressed positive signals, negative if both revealed negative signals, and equivocal if only E showed positive signals.[23] A pooling program was implemented in the laboratory informatics system (LIS) to facilitate efficiency and reduce manual errors. The pooled samples were automatically linked to a unique pooling barcode for each sample during sample reception, and the pooling barcode was then recognized by Cobas 6800. The "negative" results could be assigned to the individual samples automatically after analysis. If the result of the pool was positive, the LIS suspended the reporting, and further deconvolution was requested to identify positive samples.

Results

SARS-CoV-2 screening. Our strategies for SARS-CoV-2 screening have changed several times since the pandemic. From January 2020 to May 2021, most COVID-19 cases were those infected overseas. Thus, we only selected donors through questionnaires according to their travel, contact, or cluster history, who may be at a higher risk of SARS-CoV-2 infection. Thirteen donors completed the questionnaires as well as basic blood and stool tests during this period. However, due to the increasing risk of community infection in the local population in Taiwan and the strict policy of access control in our

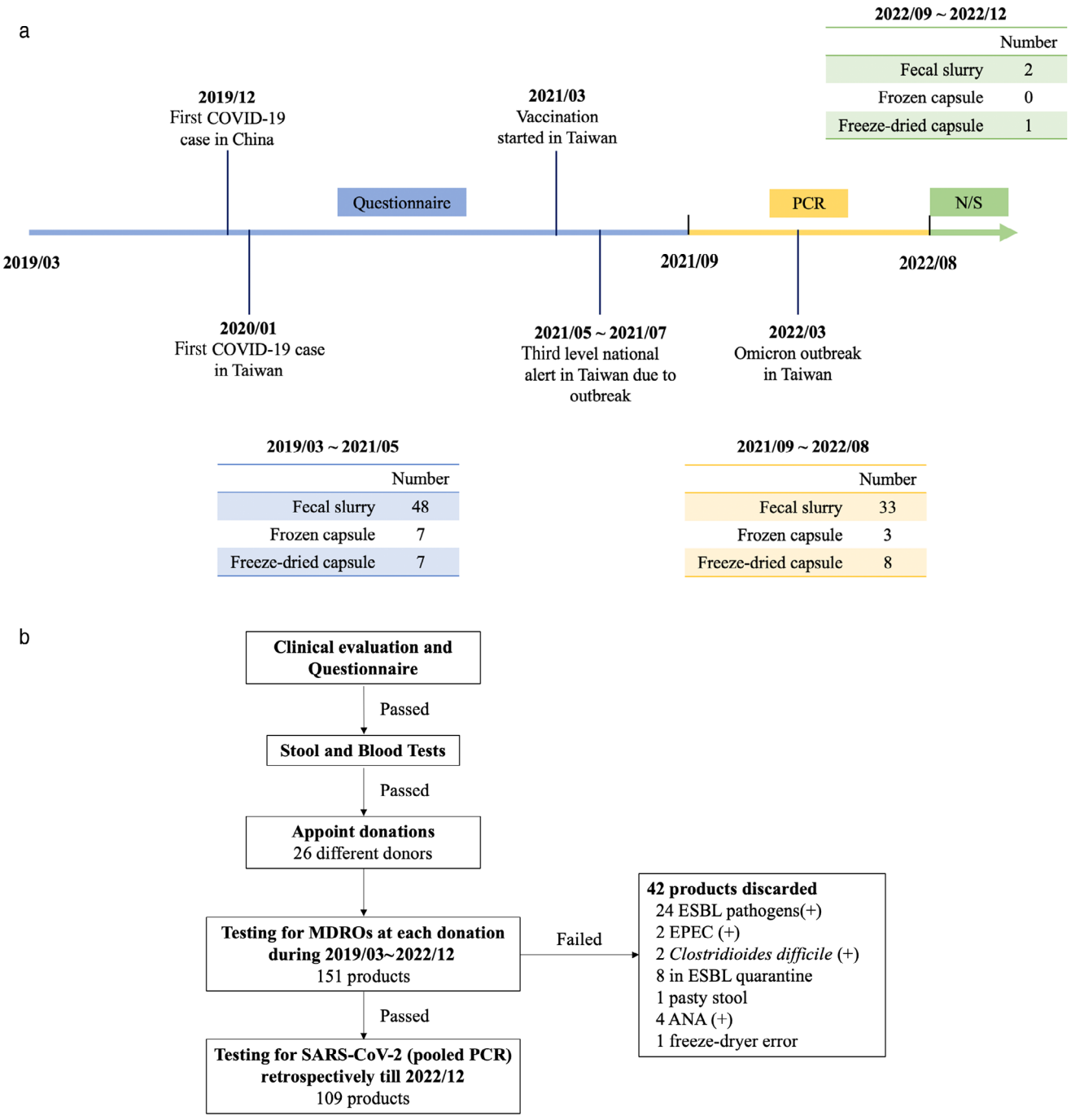

Figure 3 The rolling adjustment of coronavirus disease-2019 (COVID-19) screening in fecal microbiota transplantation (FMT) products donation in our FMT center. (a) Donors with a high-risk history of traveling, contact, or cluster were excluded from the questionnaires from March 2019 to May 2021. No fecal products were collected from May 2021 to September 2021 because of the outbreak of COVID-19 in Taiwan. After September 2021, owing to the rising risk of community infection in Taiwan, a nasopharyngeal swab for polymerase chain reaction (PCR) testing was added to the screening protocol. (b) The flowchart of multidrug-resistant organism (MDRO) and COVID-19 screening for fecal products. ANA, anti-nuclear antibody; EPEC, enteropathogenic *Escherichia coli*; ESBL, extended-spectrum beta-lactamase-producing pathogens; FC, freeze-dried capsule; N/S, spike (S) or nucleocapsid (N) proteins of SARS-CoV-2; SARS-CoV-2, severe acute respiratory syndrome coronavirus 2.

institution after May 2021, donor screening was postponed for approximately 4 months. In September 2021, we started the protocol for SARS-CoV-2 PCR testing with a nasopharyngeal swab at donor screening. From September 2021 to August 2022, 13 healthy donors passed the screening protocol but had negative results for the SARS-CoV-2 antigen rapid test at each

stool donation. None of the donors donated because of SARS-CoV-2 infection during this period.

From March 2019 to May 2021, 7 volunteers were precluded from donation screening due to new-onset symptoms of the respiratory tract within 1 month before the questionnaire, and 19 were precluded due to travel abroad after December 2019. From September 2021 to August 2022, five volunteers were excluded from donation screening because of new-onset symptoms of the respiratory tract, and three were excluded because of a contact history of suspected or confirmed cases of COVID-19. No individuals were excluded from the screening due to a history of traveling abroad or taking care of COVID-19 patients within 3 months before the questionnaire. Finally, from September 2022 to October 2022, one volunteer was precluded due to new-onset respiratory symptoms, one was precluded due to traveling abroad, and three were excluded because of a contact history of suspected or confirmed cases of COVID-19.

A total of 109 fecal products provided by 26 donors from March 2019 to December 2022 were tested using pooling methods. Among these products, 31 were collected in 2019, 16 in 2020, 33 in 2021, and 29 in 2022. This period includes the transition period of the screening protocol. To verify the safety of these products, they were divided into groups for the pooling test. All patients tested negative for SARS-CoV-2 infection.

Furthermore, from September 2021 to December 2022, two volunteers were excluded during the screening process because of positive SARS-CoV-2 PCR results from the nasopharyngeal swab. In addition, none of the donors was delayed from fecal donation due to SARS-CoV-2 infection.

MDRO detection. Between March 2019 and August 2022, 151 fecal products were collected from 26 different donors (36 person-times due to revisits) in our FMT center. Fourteen of the 26 donors (53.8%) failed steady donations because of ESBL detection during fecal donations. Most donors failed within the first month of the serial donations. Only one donor remained free of MDRO during sequential stool donation for 102 days. Among these products, 37 were discarded because of the presence of pathogenic organisms, of which 24 were positive for ESBL organisms, 2 had EPEC, and 2 had *C. difficile*. In addition, eight products that were negative for pathogens were abandoned because the former and latter feces donated by the same donor were both positive for ESBL pathogens. However, four products were discarded because the donor was found to be positive in blood tests for antinuclear antibodies (ANAs). One product was disposed of because of a Bristol scale of 6 on donation. One product was discarded owing to freeze-dryer error. The remaining 109 fecal products were stored for further use.

Therapeutic efficacy. From December 2019 to December 2022, 31 FMTs were performed on 29 patients with recurrent or refractory CDI in our center. Among them, two patients received FMT twice. One patient was cured after the second course of FMT and the other had persistent diarrhea after the second course due to antibiotic use. One patient had recurrent CDI after the first FMT but was unable to receive another course of FMT treatment due to an underlying illness. Three patients were still in the initial stages of observation after FMT. Among the 31 FMTs, 22 were performed via colonoscopy, 4 via frozen capsules, and 5 via freeze-dried capsules. The success rate of the FMT was 92.3%. None of the patients had SARS-CoV-2 infection or reported MDRO infection after the procedure.

Discussion

In the present study, we ascertained that the fecal products in our FMT center were free of MDRO and SARS-CoV-2. The strict screening protocol guarantees product quality. Our strategy for SARS-CoV-2 screening was adjusted instantly as the pandemic trend changed. The retrospective pooled PCR examination revealed that the fecal products remained free of SARS-CoV-2 even during the period when screening relied only on the questionnaire. Serial rapid antigen tests at each donation can further ensure the safety of fecal products during the window period from screening to donation. Our MDRO screening protocol was established even before the FDA recommendation. Both approaches achieved admirable accomplishment of safety issues and were beneficial for the operation of FMT.

Since the COVID-19 outbreak, the possibility of SARS-CoV-2 transmission via FMT has attracted much attention. The possibility of virus shedding into the stool and its prolonged existence in the gastrointestinal tract threaten the safety of fecal products.[6] Besides, community infection with COVID-19 occurred until May 2021. Therefore, a protocol for SARS-CoV-2 screening among donors before stool collection was not established from 2019 to 2021. Implicit transmission before this time point is also considered. Thus, screening for SARS-CoV-2 is crucial to ensure the safety and quality of storage.[7–9]

Strategies for SARS-CoV-2 screening included a standard questionnaire on clinical exposure and symptoms of COVID-19, nasopharyngeal swab and serology for SARS-CoV2 at recruitment, and periodic questionnaires and rapid stool tests for SARS-CoV-2 at serial donations.[7] These strategies have been adopted by different institutions.[24–27] The number of qualified donors declined significantly under this strict protocol.[25,27] Khanna *et al.* reported a protocol for COVID-19 symptom assessment every 2 weeks for all donors and serology tests for anti-SARS-CoV-2 IgG or PCR on nasopharyngeal swab every 2 weeks for donors and recipients.[24] Although the protocol was applied only on a small number of donors, it presented a safety profile for FMT. SARS-CoV-2 transmission was not observed. Groenewegen *et al.* from the Netherlands adopted a similar protocol, and two donors developed mild symptoms of COVID-19 and were later confirmed to be infected.[26] Both donors were immediately prevented from stool donations. The patients underwent repeated PCR and anti-SARS-CoV-2 IgG tests. One of the infected donors tested negative for SARS-CoV-2 PCR 6 weeks after symptom onset and negative for anti-SARS-CoV-2 IgG after 28 weeks.[26] No significant decline in the efficacy of FMT has been reported.[26]

However, the cost of nucleic acid amplification tests is high if the specimens are tested separately. Hence, a pooling method was introduced into the program. The pooling method for PCR was applied for routine checkups with nasal swabs in patients who underwent endoscopic examination, surgery, or admission at our institution.[23] Because the prevalence of community infection was low during stool collection, the samples were assumed to be negative in the nucleic amplification test. This

method allowed us to examine multiple samples at once but had little chance to confirm positive results. The pooling method is reliable and time saving. Furthermore, the cost of nucleic acid amplification tests decreased from NT$3500 to NT$950 per sample.

Currently, our center approves only healthy individuals without a previous COVID-19 infection for donor recruitment. However, whether a previously healthy individual who had recovered from COVID-19 infection could be recruited is another issue to debate.[28] Although the prolonged presence of SARS-CoV-2 in stool of infected individuals would eventually subside,[7,26,28] individuals who have recovered from COVID-19 may have an altered composition of gut microbiota and distorted metabolic status of bile acids and short-chain fatty acids. Whether stool from post-COVID-19 individuals has the same therapeutic efficacy as that from non-infected individuals remains uncertain. Nevertheless, the proportion of non-infected individuals decreased after the COVID-19 pandemic. Donor recruitment would be difficult if healthy individuals were excluded, but only once were COVID-19-infected individuals excluded. Thus, evaluating the changes in microbial metabolism in COVID-19-infected individuals is important for stool banks in the future.

From August 2019 to August 2022, more than half of the donors failed to maintain sequential donations because of MDRO, and approximately 18% of the collected stool products were discarded because of MDRO detection. We used various strategies to reduce the recruitment of MDRO carriers during donor selection. We also suggested donors who passed screening tests to maintain dietary hygiene and avoid entering medical institutions during the period of donation. Furthermore, our members sterilized the toilet used by donors at each stool donation with 75% alcohol every time. These approaches were aimed to maintain qualified donors and reduce the wastage caused by newly discovered MDRO carriages during donation. The details of donor screening in our group had been reported earlier.[11] Briefly, about 78.6% individuals were excluded by questionnaire, and only 5.0% individuals were qualified at the final stage.[11] The success rate of donor screening ranged from 0.8 to 11.9% in centers of the United States, Australia, Hong Kong, and China.[12–16,25–27,29,30] The criteria for donor selection were similar in different countries. In these leading FMT institutions, the online questionnaire and clinical assessment could help exclude most of the unqualified donors, which ranged from 65.2 to 92%. A strict clinical assessment could avoid unnecessary costs on further gastrointestinal pathogens and serologic screening.[12–16,25,27,30] These institutions also followed the recommendation of the FDA, such as screening for MDROs and SARS-CoV-2. Furthermore, some centers in China had protocols of bacterial composition assessment via stool sequencing during the screening process.[27,30]

Although the COVID-19 seems to have ended, there are still possibilities of emerging infectious diseases in the future. The ways in which infectious diseases spread vary. To ensure the safety of stool donation, it is crucial for us to constantly monitor international trend about emerging infectious diseases to promptly adjust the questionnaire for donor screening and to modify the blood or fecal tests based on the natural history of disease transmission. Moreover, we have constantly monitored protocols for donors and recipients. If the donors have suspected symptoms or signs of emerging infectious diseases after stool donation, the fecal products collected during the incubation period will be turned to quarantine until further validation. If the donors are confirmed to be victims of emerging infectious diseases, the serial fecal products will be discarded. For recipients who had possible infection after FMT, we would trace back the fecal products and donors for additional confirmation.

In conclusion, our FMT center established protocols to provide MDRO- and SARS-CoV-2-free products before and during the COVID-19 pandemic. SARS-CoV-2-free fecal products could be guaranteed under current protocols by using questionnaires and nasopharyngeal swabs during screening and rapid antigen tests during each donation. Moreover, using a pooling method for SARS-CoV-2 detection in fecal products is a time- and cost-saving method for large-quantity specimen examination for the retrospective confirmation of product safety. Although MDRO-free products can be ensured by current methods, the rate of screening failure or donation postponement due to MDRO carriage is high. Finding a way to efficiently reduce the rate of stool donation due to MDRO colonization remains a challenge in the future.

References

1 van Nood E, Vrieze A, Nieuwdorp M *et al*. Duodenal infusion of donor feces for recurrent *Clostridium difficile*. *N. Engl. J. Med.* 2013; **368**: 407–15.
2 Mullish BH, Quraishi MN, Segal JP *et al*. The use of faecal microbiota transplant as treatment for recurrent or refractory *Clostridium difficile* infection and other potential indications: joint British Society of Gastroenterology (BSG) and Healthcare Infection Society (HIS) guidelines. *Gut*. 2018; **67**: 1920–41.
3 Cammarota G, Ianiro G, Kelly CR *et al*. International consensus conference on stool banking for faecal microbiota transplantation in clinical practice. *Gut*. 2019; **68**: 2111–21.
4 DeFilipp Z, Bloom PP, Torres Soto M *et al*. Drug-resistant *E. coli* bacteremia transmitted by fecal microbiota transplant. *N. Engl. J. Med.* 2019; **381**: 2043–50.
5 Carlson PE Jr. Regulatory considerations for fecal microbiota transplantation products. *Cell Host Microbe*. 2020; **27**: 173–5.
6 Xu Y, Li X, Zhu B *et al*. Characteristics of pediatric SARS-CoV-2 infection and potential evidence for persistent fecal viral shedding. *Nat. Med.* 2020; **26**: 502–5.
7 Ianiro G, Mullish BH, Kelly CR *et al*. Reorganisation of faecal microbiota transplant services during the COVID-19 pandemic. *Gut*. 2020; **69**: 1555–63.
8 Ianiro G, Mullish BH, Kelly CR *et al*. Screening of faecal microbiota transplant donors during the COVID-19 outbreak: suggestions for urgent updates from an international expert panel. *Lancet Gastroenterol. Hepatol.* 2020; **5**: 430–2.
9 Green CA, Quraishi MN, Shabir S *et al*. Screening faecal microbiota transplant donors for SARS-CoV-2 by molecular testing of stool is the safest way forward. *Lancet Gastroenterol. Hepatol.* 2020; **5**: 531.
10 Lee PC, Chang TE, Wang YP *et al*. Alteration of gut microbial composition associated with the therapeutic efficacy of fecal microbiota transplantation in *Clostridium difficile* infection. *J. Formos. Med. Assoc.* 2022; **121**: 1636–46.
11 Chuang C, Lee KC, Wang YP *et al*. High carriage rate of extended-spectrum β-lactamase enterobacterales and diarrheagenic *Escherichia*

coli in healthy donor screening for fecal microbiota transplantation. *Eur. J. Clin. Microbiol. Infect. Dis.* 2023; **42**: 1103–13.
12 Hamilton MJ, Weingarden AR, Sadowsky MJ, Khoruts A. Standardized frozen preparation for transplantation of fecal microbiota for recurrent *Clostridium difficile* infection. *Am. J. Gastroenterol.* 2012; **107**: 761–7.
13 Kassam Z, Dubois N, Ramakrishna B *et al*. Donor screening for fecal microbiota transplantation. *N. Engl. J. Med.* 2019; **381**: 2070–2.
14 Chen J, Zaman A, Ramakrishna B, Olesen SW. Stool banking for fecal microbiota transplantation: methods and operations at a large stool bank. *Front. Cell. Infect. Microbiol.* 2021; **11**: 622949.
15 Lu G, Wang W, Li P, Wen Q, Cui B, Zhang F. Washed preparation of faecal microbiota changes the transplantation related safety, quantitative method and delivery. *J. Microbial. Biotechnol.* 2022; **15**: 2439–49.
16 Tucker EC, Haylock-Jacobs S, Rapaic M, Dann LM, Bryant RV, Costello SP. Stool donor screening within a Therapeutic Goods Administration compliant donor screening program for fecal microbiota transplantation. *JGH Open*. 2023; **7**: 172–7.
17 Magiorakos AP, Srinivasan A, Carey RB *et al*. Multidrug-resistant, extensively drug-resistant and pandrug-resistant bacteria: an international expert proposal for interim standard definitions for acquired resistance. *Clin. Microbiol. Infect.* 2012; **18**: 268–81.
18 Weinstein MP, Lewis JS 2nd. The Clinical and Laboratory Standards Institute Subcommittee on antimicrobial susceptibility testing: background, organization, functions, and processes. *J. Clin. Microbiol.* 2020; **58**: e01864-19.
19 Parvathy SN, Lenehan JG, Fernandes R *et al*. Enhanced donor screening for faecal microbial transplantation during COVID-19. *Gut*. 2021; **70**: 2219–20.
20 Ng SC, Chan FKL, Chan PKS. Screening FMT donors during the COVID-19 pandemic: a protocol for stool SARS-CoV-2 viral quantification. *Lancet Gastroenterol. Hepatol.* 2020; **5**: 642–3.
21 Ben-Ami R, Klochendler A, Seidel M *et al*. Large-scale implementation of pooled RNA extraction and RT-PCR for SARS-CoV-2 detection. *Clin. Microbiol. Infect.* 2020; **26**: 1248–53.
22 Gupta E, Padhi A, Khodare A *et al*. Pooled RNA sample reverse transcriptase real time PCR assay for SARS CoV-2 infection: a reliable, faster and economical method. *PloS One*. 2020; **15**: e0236859.
23 Lee HR, Wang FY, Li JL, Chou TY, Ho HL. Real-world evaluation of a sample pooling strategy for large-scale rapid COVID-19 testing. *J. Clin. Virol.* 2022; **149**: 105133.
24 Khanna S, Tande A, Rubin DT, Khoruts A, Kahn SA, Pardi DS. Fecal microbiota transplantation for recurrent *C. difficile* infection during the COVID-19 pandemic: experience and recommendations. *Mayo Clin. Proc.* 2021; **96**: 1418–25.
25 Yau YK, Mak WYJ, Lui NSR *et al*. High prevalence of extended-spectrum beta-lactamase organisms and the COVID-19 pandemic impact on donor recruitment for fecal microbiota transplantation in Hong Kong. *United European Gastroenterol J.* 2021; **9**: 1027–38.
26 Groenewegen B, van Lingen E, Ooijevaar RE *et al*. How to prepare stool banks for an appropriate response to the ongoing COVID-19 pandemic: experiences in the Netherlands and a retrospective comparative cohort study for faecal microbiota transplantation. *PloS One*. 2022; **17**: e0265426.
27 Zhang S, Chen Q, Kelly CR *et al*. Donor screening for fecal microbiota transplantation in China: evaluation of 8483 candidates. *Gastroenterology*. 2022; **162**: 966–8.e3.
28 Kazemian N, Kao D, Pakpour S. Fecal microbiota transplantation during and post-COVID-19 pandemic. *Int. J. Mol. Sci.* 2021; **22**: 3004.
29 Tariq R, Weatherly R, Kammer P, Pardi DS, Khanna S. Donor screening experience for fecal microbiota transplantation in patients with recurrent *C. difficile* infection. *J. Clin. Gastroenterol.* 2018; **52**: 146–50.
30 He J, He X, Ma Y *et al*. A comprehensive approach to stool donor screening for faecal microbiota transplantation in China. *Microb. Cell Fact.* 2021; **20**: 216.