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Original Article

Linkage of the CF Foundation Patient Registry with the Scientific Registry of Transplant Recipients database

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ABSTRACT

Background: The Cystic Fibrosis Foundation Patient Registry (CFFPR) maintains clinical data, including history of solid organ transplant, on people with cystic fibrosis (CF) who obtain care at CF Foundation-accredited care centers. The Scientific Registry of Transplant Recipients (SRTR) database is a collection of national data related to organ transplantation that supports research to evaluate solid organ transplant candidate and recipient outcomes.

Methods: Individuals in the CFFPR were matched to SRTR records using an algorithm that compared names, last four digits of social security numbers, date of birth and date of death. We evaluated match quality by summarizing the extent to which transplant status agreed between the two data sources by organ and year of listing or transplant. We summarized CFFPR-reported characteristics for lung and liver transplants in the year prior to transplant.

Results: A total of 7,594 individuals who participated in the CFFPR matched SRTR records with approximately 75% having at least one transplant record in SRTR. Over 97% of the matched population had a CF diagnosis reported to SRTR. In total, 5,253 people were identified as lung transplant recipients and 499 as liver transplant recipients in SRTR. Clinical characteristics for lung and liver transplants were consistent with the epidemiology of transplantation for people with CF.

Conclusions: Linkage of the two data sources was successful, with high agreement between them supporting the use of the matched population as a valid resource to study transplantation in CF, particularly leveraging pre-transplant characteristics (collected in CFFPR) with detailed transplant data (collected in SRTR).

1. Introduction

Cystic fibrosis (CF) is an autosomal recessive disease that causes dysfunction of the cystic fibrosis transmembrane conductance regulator (CFTR) protein, resulting in impaired mucus hydration which leads to pulmonary infection and inflammation [1]. People with CF (PwCF) also experience comorbidities in addition to respiratory illnesses, including pancreatitis, CF-related diabetes, liver disease, and malnutrition. Lung transplantation is a therapeutic option for late-stage lung disease and accounts for the majority of transplants reported among PwCF in the United States [2]. While far less frequent, liver transplantation is indicated for PwCF who experience advanced CF hepato-biliary

involvement (CFHBI) [3]. Additionally, kidney, and other solid organ transplants are also reported to the CF Foundation Patient Registry (CFFPR) every year [4].

The CFFPR maintains diagnosis, demographic and clinical data from 1986 to the present on PwCF who obtain care at CF Foundation-accredited care centers in the United States [5]. Individuals seen at CF care centers (or their guardians for minors) provide informed consent for their data to be used for research purposes. The CFFPR includes longitudinal data from routine CF care such as pulmonary function testing and airway culture surveillance, hospitalizations, survival, transplantation and other CF-related co-morbidities such as sinus disease, diabetes, and CFHBI. The CFFPR does not collect transplant-specific

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details such as donor characteristics or peri-operative clinical indicators. The Scientific Registry of Transplant Recipients (SRTR) database is a collection of national data related to organ transplantation in the United States; SRTR data and analyses support research to evaluate the outcomes of solid organ transplant candidates and recipients, inform policy decisions related to organ allocation, and monitor quality improvement efforts. SRTR data have been linked previously to other registry and large administrative datasets [6–10].

Although a recent position paper outlines shared models of care for PwCF [11], some individuals with CF obtain care at their transplant center which may not be affiliated with a CF care center. As data can only be reported to CFFPR through an accredited CF care center, these individuals become lost to follow-up [12]. Missing or incomplete transplant information limits the use of CFFPR data alone to test hypotheses related to pre-transplant characteristics and their association with post-transplant outcomes. There are likely additional modifiers of post-transplant outcomes associated with the waitlist and peri-operative periods that are not captured in the CFFPR. Previous studies measuring the association between CF disease characteristics on post-transplant outcomes among PwCF have been limited to transplant center-specific cohorts with small sample size [2,13] or only evaluated survival [14]. Linking CFFPR participants to their corresponding transplant and post-transplant data in SRTR provides a unique opportunity to identify pre-transplant risk factors associated with adverse outcomes and identify barriers to transplant care among PwCF.

Linkage of the CFFPR to post-transplant data has been successful in the past, and several studies demonstrate the utility of linking the CFFPR to transplant data for a variety of research objectives including estimation of post-transplant survival in children [15], evaluating the impact of changes to the Lung Allocation Score (LAS) [16], and characterizing differences in the transplant population between the United States and Canada [17], in addition to other secondary analyses [18–22]. Given the administrative burden and analytical complexity of creating a linked dataset, we aimed to operationalize a linkage between the CFFPR and the SRTR for all solid organ transplant recipients. The objective of this analysis was to characterize data availability and generalizability of the linked dataset to aid investigators planning studies using the linked dataset.

2. Methods

2.1. Data sources

In 2022, 32,621 individuals reported data to the CFFPR [4]. During a patient's annual review, CF care teams document the most recent transplant status: accepted to the waiting list, evaluated but pending a final decision, evaluated and rejected, or transplanted. CF care teams can then report the date of the most recent solid organ transplant for the following categories: lung (bilateral; lobar/cadaveric; lobar/living donor); heart/lung; liver; kidney; or other. In the event an individual obtains care at more than one CF care center, data are reconciled into a single patient record. Transplant status can change over time to reflect updates that include evaluation, placement on the waiting list, or re-transplantation. Since 2010, CFF has verified reported transplants with each CF care team after annual reporting is complete. An audit of the CFFPR conducted in 2012 demonstrated a high level of agreement between medical records for 82.6–99.9% of recorded variables [5] and approximately 80% of PwCF in the United States currently participate [23]. Since 2019, CF care teams can also report additional data on lung transplant referral details, evaluation results and transplant program(s) for PwCF meeting criteria for advanced CF lung disease [24].

The SRTR data system includes data on all donors, waitlisted candidates, and transplant recipients in the U.S., submitted by the members of the Organ Procurement and Transplantation Network (OPTN), and has been described elsewhere [25]. The Health Resources and Services Administration (HRSA), U.S. Department of Health and Human Services,

provides oversight of the activities of the OPTN and SRTR contractors. The SRTR collects and maintains data regarding organ transplantation in the United States. Data are derived from multiple sources including the OPTN, transplant programs, organ procurement organizations, histocompatibility laboratories, the Centers for Medicare and Medicaid Services (CMS), and the National Technical Information Service's (NTIS) Limited Access Death Master File. The SRTR database includes data from every organ transplant and waitlist addition within the U.S. since October 1987.

2.2. Database linkage methods

Individuals with a reported CF diagnosis who participated in the CFFPR at any time between 1986 and 2020 were included in the finder file shared with the SRTR. Database linkage was performed using a deterministic matching algorithm including the last four digits of the social security number, first name, last name, middle initial, birth date, and death date (when applicable). The SRTR implemented the linkage assigning a score to each individual record based on the extent to which different combinations of identifiers were exact matches. Underlying reason (i.e., diagnosis) for waitlist or transplant reported to SRTR was extracted for the first available record per person.

2.3. Statistical analysis

To evaluate the linkage, we calculated the number of individuals with waitlist and transplant records by organ as documented in SRTR: heart/lung; heart; intestine; kidney; kidney/pancreas; liver; lung; and pancreas. For comparison to CFFPR-reported transplants, SRTR-reported heart, intestine, kidney/pancreas and pancreas transplants were combined as "other". We further enumerated linked individuals by reason reported to SRTR at the time of waitlist or transplant. Since the CFFPR does not report waitlist status by organ, we compared agreement between CFFPR and SRTR according to waitlist data for any organ. The CFFPR does not differentiate changes in transplant or waitlist status that occur in the same calendar year; we assumed an individual with a CFFPR-reported transplant in a given year was also waitlisted if no report of waitlist was available from a prior year.

We summarized the proportion of records by matching criteria and the number of individuals for which the reported organ transplant agreed between the two datasets. SRTR report of transplant was considered "gold standard". Since the CFFPR began verification of transplant and death reports in 2010, we calculated the cumulative proportion of first organ transplant by year. As name changes may disproportionately affect females and given the possibility that surnames of non-English origin might be less likely to match than common American surnames, we compared the proportion of people with female sex, Hispanic ethnicity and any Black, Indigenous, People of Color (BIPOC) race categories by data source and organ transplanted. Finally, to characterize the linked population, we calculated summary statistics using CFFPR-reported demographic and clinical data for individuals in the year prior to first transplant (as reported in the CFFPR) for lung and liver transplant recipients who had a transplant reported in both data sources. For the purpose of evaluating the matched population with a history of lung transplant, we restricted those reported in 2005 or later years to account for the introduction of the lung allocation score [16].

The matched analysis was determined exempt from IRB oversight by Advarra institutional review board (#00065292). All analyses were conducted using SAS version 9.4 and R version 4.0.5.

3. Results

A finder file with a total 54,505 individuals who have ever participated in the CFFPR from 1986 to 2020 with a reported CF diagnosis was shared with SRTR for linkage. We excluded 16 people who matched to more than one SRTR ID and 71 people who matched to living donor or

deceased donor records with no other transplant record. A total of 7594 CFFPR participants matched to at least one record in SRTR, of which 7593 (99.9%) had a waitlist record reported and 5715 (75.3%) had a transplant record in SRTR. A total of 6263 of individuals matched on some combination of the last four digits of the social security number, first name, last name, date of birth and date of death; with 50% of people matching exactly on last four digits of the social security number, last name, first name, date of birth and date of death. Among the matched sample, social security number data was missing in SRTR for 68 people. Another 13% matched exactly on first name, last name, date of birth and date of death. The remaining 8% matched on some combination of elements of names, birthdate or death date as outlined in Supplemental Information (SI) Table 1.

A total of 7390 unique individuals (97.3%) in the matched dataset were identified to have at least one SRTR record with CF as a primary diagnosis based on waitlist or transplant data (99% of lung transplant recipients and 90% of liver transplants). Excluding the individuals who matched to the CFFPR, SRTR includes an additional 809 people with CF as a primary diagnosis reported on the thoracic waitlist or transplant datasets. SI Table 2 presents the proportion of matched CFFPR/SRTR individuals and individuals with a CF diagnosis in SRTR who did not match to the CFFPR by year of first listing. From 2000–2020, individuals with CF who did not match comprised between 5 and 10% of the total people with CF listed in the year. We summarized individual characteristics as reported to SRTR at time of listing comparing matched and unmatched individuals in SI Table 3. Overall, 97% of people found in both datasets had a CF diagnosis documented in SRTR and the linked population accounts for 90% of all individuals waitlisted or transplanted with a CF diagnosis reported to SRTR.

Table 1 presents the total number of CFFPR participants by waitlist and transplant SRTR record match. A total of 6386 individuals were classified in this analysis as ever waitlisted in the CFFPR in at least one calendar year: 979 had at least one year with a waitlist status reported but no subsequent transplant documented; 1542 had both a waitlist and transplant status for any organ reported and 3865 had a report of transplant (for any organ) without a previous year report of being waitlisted in the CFFPR (Table 1). Of the 3865 individuals with only a transplant reported in CFFPR, 3633 people (94%) had a waitlist or transplant record identified in SRTR, with 3625 individuals matching to both a waitlist and transplant record. A total of 4708 individuals identified as waitlisted or transplanted (for any organ) in the CFFPR matched to an SRTR record reporting at least one lung transplant. An additional 1769 individuals with no history of waitlist or transplant reported to the CFFPR matched to SRTR records: 458 (25%) of these individuals had a lung transplant record in SRTR. SI Table 4 presents the total number of matched lung and liver recipients by year of listing.

A total of 5715 people in the CFFPR matched to at least one transplant record in SRTR. Among all individuals with any transplant record in SRTR, 376 were classified by SRTR as multiorgan transplants. The number of individuals with a reported transplant by organ type is presented in Table 2, with 5253 individuals matching to a lung transplant

record reported in SRTR. While the following organ-specific data is not available in the CFFPR, SRTR reported a total of 10 heart only, 15 kidney/pancreas, 29 pancreas only, and 10 intestine transplants among PwCF in both datasets. Agreement between reported transplant status between CFFPR and SRTR was highest for lung transplants, with 4705 (90%) people identified as lung transplant recipients in both data sources. Among those reported as having a liver transplant in SRTR, 86% had a corresponding report of liver transplant in the CFFPR. Agreement between the two data sources was lower for heart/lung (69%), kidney (57%) and other organs combined (64%). Nearly all (99%) of SRTR documented lung transplant recipients indicated a CF diagnosis; 90% of liver transplant recipients and 89% of kidney transplant also recipients had a CF diagnosis documented in SRTR.

A total of 295 individuals were reported to have received a lung transplant in the CFFPR but had no corresponding lung transplant record in SRTR (Table 2). Only 54 (18%) of those individuals matched to any other record in SRTR. Among these individuals, 21 had a waitlist record in SRTR for lung transplant, 33 had a waitlist record for another organ, and 42 had a transplant record for a different solid organ in SRTR. The proportion of discrepant records (transplant data reported in CFFPR but not reported in SRTR) was highest in earlier years, as 60% of these individuals reported a first lung transplant prior to the start of transplant verification by the CFFPR in 2010. An additional 44 people were reported to have a liver transplant in the CFFPR (with no corresponding SRTR liver transplant record): 18 had report of liver waitlist record and 15 reported transplants for other organs. The majority of these individuals (77%) had a liver transplant reported to the CFFPR prior to 2010. A total of 22 individuals had a report of a kidney transplant in CFFPR but no matching transplant record in SRTR: 17 were identified by SRTR as other organ transplant recipients and 8 had a waitlist record for kidney. In contrast to lung and transplants, 90% of kidney transplants reported to CFFPR but not reported in SRTR had a first transplant year 2010 or later.

Among those with a CFFPR report of lung transplant but no SRTR record, a higher proportion were female (51%) compared to those with a lung transplant in both data sources (49.6%) or SRTR only (47.2%). A similar pattern was observed among liver transplant recipients: 43.2% female among CFFPR only reported transplant compared to 38.0% for those in both CFFPR and SRTR. Comparing the matched population to those unmatched with a CF diagnosis in SRTR, 17% of Latino individuals did not match compared to 9% of non-Latino; Individuals with SRTR-reported BIPOC race had higher proportions of unmatched individuals in the linkage (SI Table 3). Hispanic ethnicity was much more prevalent among those with a CFFPR reported transplant but no corresponding match in SRTR for lung and liver transplants. The distribution of female sex, any BIPOC race, and Hispanic ethnicity (as reported to CFFPR) by source of organ transplant report is presented in SI Table 5.

In Table 3, we summarized subject characteristics in the calendar year preceding the first transplant as reported to CFFPR for individuals for whom their first transplant was either lung or liver (not both). A total of 2872 individuals matched to SRTR by lung transplant (first

Table 1
Summary of individuals matched to SRTR by CFFPR waitlist and transplant reporting.

| CFFPR transplant status* | Total persons in CFFPR | Total persons with SRTR match n (%) | SRTR Records Matched* | | | | |
|------------------------------------|------------------------|-------------------------------------|-----------------------|-----------------------|----------------------|-----------------------|------------------------|
| | | | Waitlist record (n) | Transplant record (n) | Lung transplants (n) | Liver transplants (n) | Kidney transplants (n) |
| Waitlist only | 979 | 709 (72%) | 709 | 90 | 87 | <5** | <5** |
| Waitlist and transplant | 1542 | 1483 (96%) | 1483 | 1476 | 1382 | 135 | 67 |
| Transplant only | 3865 | 3633 (94%) | 3633 | 3625 | 3326 | 308 | 241 |
| No waitlist or transplant reported | 48,119 | 1769 (4%) | 1768 | 524 | 458 | <60** | <30** |

* CFFPR waitlist reporting is not organ-specific; CFFPR counts represent unique individuals included in the linkage ($n = 54,505$). The number of SRTR records matched reflects the total number of people found with an organ transplant as reported in the SRTR and counts per organ could include the same person more than once if more than one type of organ transplant was reported.

** Counts suppressed to comply with CFFPR privacy guidelines.

Table 2
Summary of individuals with waitlist and transplant status by solid organ through 2022.

| Organ | Individuals with waitlist record in SRTR (n)** | Individuals with transplants reported in SRTR (n) | Individuals with transplant reported in CFFPR (n) | Individuals with transplant reported in both data sources (n) [†] | % of individuals reported by SRTR with transplant documented in CFFPR |
|----------------|--|---|---|--|---|
| Heart/ Lung | 131 | 43 | 65 | 30 | 69% |
| Kidney | 537 | 340 | 217 | 195 | 57% |
| Liver | 750 | 499 | 472 | 428 | 86% |
| Lung | 6956 | 5253 | 5000 | 4705 | 90% |
| Other* | 141 | 57 | 165 | 36 | 64% |

* Other combines any SRTR reported heart, kidney/pancreas, pancreas and intestine.

** Totals do not represent mutually exclusive individuals. CFFPR does not document waitlist status by organ.

† Total number of people for whom both data sources reported the same type of organ transplanted.

Table 3
Subject characteristics in the calendar year preceding a first transplant as reported to CFFPR.

| Characteristic (calendar year preceding transplant) | Lung (n = 2872) | Liver (n = 347) |
|--|---------------------|---------------------|
| Transplanted Pre-2005 | 0 (0.0%) | 155 (43.9%) |
| Transplanted 2005 to 2009 | 803 (27.8%) | 38 (10.8%) |
| Transplanted 2010 to 2014 | 910 (31.5%) | 52 (14.7%) |
| Transplanted 2015 to 2022 | 1178 (40.7%) | 108 (30.6%) |
| Age at year end (IQR) | 28.8 (23.0–37.2) | 14.9 (10.7–20.4) |
| <i>Age Category</i> | | |
| Age ≤18 | 294 (10.2%) | 241 (68.3%) |
| Age >18 | 2597 (89.8%) | 112 (31.7%) |
| Age at CF diagnosis (IQR) | 0.5 (0.2–2.7) | 0.4 (0.1–2.0) |
| <i>Race/ethnicity</i> | | |
| White | 2808 (97.1%) | 339 (96.0%) |
| Any Hispanic | 180 (6.2%) | 24 (6.8%) |
| Any BIPOC race | 92 (3.2%) | 16 (4.5%) |
| Female sex | 1450 (50.2%) | 134 (38.0%) |
| <i>CFTR genotype</i> | | |
| F508del homozygous | 1386 (47.9%) | 195 (55.2%) |
| F508del heterozygous | 1057 (36.6%) | 109 (30.9%) |
| No F508del allele | 288 (10.0%) | 27 (7.6%) |
| Missing | 141 | 16 |
| Annualized BMI (IQR) | 19.9 (18.3–21.9) | 21.3 (19.5–23.4) |
| Annualized FEV1pp (IQR) | 28.2 (23.2–34.2) | 71.4 (54.4–83.4) |
| <i>ppFEV1 Category</i> | | |
| <40 | 2481 (85.8%) | 43 (12.2%) |
| 40–70 | 335 (11.6%) | 106 (30.0%) |
| >70 | 13 (0.4%) | 166 (47.0%) |
| Missing | 43 | 32 |
| <i>Health Insurance*</i> | | |
| Private | 1695 (58.6%) | 216 (61.2%) |
| Medicare/Medicaid/Indian Health** | 1634 (56.5%) | 192 (54.4%) |
| Other or no insurance | 105 (3.6%) | 5 (1.4%) |
| <i>Education</i> | | |
| Less than high school/high school diploma/ some college | 1484 (51.3%) | *** |
| College/graduate degree | 823 (28.5%) | *** |
| <i>Employment</i> | | |
| Full time employment | 472 (16.3%) | *** |
| Any other employment | 2153 (74.5%) | *** |
| <i>CF Complications</i> | | |
| ABPA | 270 (9.3%) | 15 (4.2%) |
| Hemoptysis | 235 (8.1%) | 18 (5.1%) |
| Liver disease, cirrhosis | 76 (2.6%) | 151 (42.8%) |
| Anxiety | 414 (14.3%) | 18 (5.1%) |
| Depression | 912 (31.5%) | 34 (9.6%) |
| Any diabetes | 1402 (48.5%) | 113 (32.0%) |

* Insurance categories are not mutually exclusive.

** Includes Indian Health services/state programs/TriCare or other military.

*** Education and employment status only reported in adults >18 years of age.

transplant) were reported to the CFFPR between 2005 and 2022 and had CFFPR data corresponding to the calendar year preceding the transplant. Nearly 41% of these individuals were transplanted between 2015 and 2022, with a median age of 28.8 years (IQR: 23.0; 37.2). Liver transplant recipients (n = 347, transplanted in any year) were predominantly children, with a median age of 14.9 (IQR: 10.7; 20.4). Liver transplant recipients were also far less likely to be female (36.3%). The proportion of people that reported private health insurance was similar for both lung and liver transplants. While a detailed review of the loss-to-follow-up (LTFU) population is beyond the scope of this analysis, we found 1802 people with no death date reported and no annual or encounter-level data reported to CFFPR in 2022 were matched to at least one SRTR record (waitlist or transplant events may have occurred prior to being LTFU from CFFPR).

4. Discussion

This study summarizes the most inclusive linkage of CFFPR and SRTR and includes both waitlist and transplantation records for all solid organ types. Prior linkages were limited to specific time periods or populations. This updated linkage covers the full time series of the CFFPR, allowing individuals who entered the CF Registry at any point between 1986 and 2020 and may have been waitlisted or transplanted through the end of 2022 to be included.

We used several identifiers to establish the linkage, including the last four digits of the social security number. Unlike the previous linkages, we demonstrated agreement between CFFPR and SRTR by the reason for transplant reported at the time of first waitlist or transplant. We found 90% of all people with a CF diagnosis reported to SRTR were identified in the linked dataset, consistent with estimates of participation in the CFFPR (approximately 90% of prevalent people with CF as of 2020 have been included in the CF Registry) [23]. Agreement between CFFPR reported and SRTR documented transplants was 90% for lung transplants and 86% for liver transplants. Patient characteristics in the year before transplant reflect the epidemiology of transplantation among people with CF: lung transplant recipients were overwhelmingly older than age 18 years, and 86% of that population had ppFEV1 <40 in the year prior to transplant. Over 75% of liver transplant recipients were children and predominantly male, consistent with the higher prevalence of liver transplantation among male children with CF [26–28]. The few numbers of kidney transplant recipients identified in the data is consistent with the low incidence of kidney transplantation as a primary transplant for people with CF whereas risk of chronic kidney disease increases among those post-lung transplant [28,29].

While the overall results of the linkage show high agreement, reasons for an individual not being successfully matched range from discrepancies in names between the two data sources, age and calendar period of transplant, and possible loss-to-follow-up among transplant recipients who may not return to their CF care team post-transplant. We note the higher proportion of unmatched records among females and those with reported Hispanic ethnicity or BIPOC race. In the case of females, name

changes may be more likely than males and would not necessarily be documented consistently between the CFFPR and SRTR, which we speculate may result from errors matching on names (accent marks, multiple names, hyphenates, etc.). There was a higher proportion of individuals with a CF diagnosis reported to SRTR who did not match to CFFPR among those transplanted in the 1990s and early 2000s, suggesting the linked dataset may be less generalizable for studies of lung transplantation in the pre-LAS era. Those with a CF diagnosis in SRTR but not matched to CFFPR were more likely to be older than 50 years of age, which is consistent with lower participation in the CFFPR among older adults [23] but some of these individuals may also be misclassified as having CF. Due to data sharing restrictions, we were unable to perform additional validation via chart review at CF care centers or transplant centers.

The results presented in this study should enable investigators to plan their own research studies, as we have summarized the total available by waitlist or transplant status per organ, as well as number of individuals waitlisted by year for lung and liver transplants. Since the incidence of transplantation in CF has decreased to less than 100 primary lung transplants per year as of 2020 [4], we plan to update the linkage every two to three years. Investigators interested in accessing the linked dataset should submit their proposed study aims and dataset requests separately to the CFF and the SRTR. The CFF Patient Registry data application requires investigators to summarize the project personnel, outline the study objectives, summarize the statistical methods to be employed and enumerate the variables and inclusion criteria. SRTR requires submission of a research plan, data security plan, and a signed Data Use Agreement. Upon approval from both CFF and SRTR, investigators will be able to merge the two data sources using a numeric identifier to link the data sources.

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CRediT author statement

Elizabeth A. Cromwell: Conceptualization; Methodology; Software; Formal Analysis; Writing-Original draft preparation; Writing – Review and Editing. **Yoon Son Ahn:** Methodology; Validation; Software; Formal Analysis; Resources; Writing-Original draft preparation; Writing – Review and Editing. **Patrick J. Johnson:** Methodology; Software; Validation; Formal Analysis; Writing – Review and Editing. **Kathleen J. Ramos:** Conceptualization; Writing – Review and Editing. **Jay Freeman:** Writing – Review and Editing. **Albert Faro:** Conceptualization; Writing – Review and Editing; Resources, Supervision. **Jon J. Snyder:** Conceptualization; Methodology; Software; Formal Analysis; Writing-Original draft preparation; Writing – Review and Editing;

Resources, Supervision.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.jcf.2024.09.015.

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