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Authors
Bayne, David
Srirangapatanam, Sudarshan
Hicks, Cameron R
et al.

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Community Income, Healthy Food Access, and Repeat Surgery for Kidney Stones

David Bayne, Sudarshan Srirangapatanam, Cameron R. Hicks, Manuel Armas-Phan, Amy Showen, Anne Suskind, Hilary Seligman, Kirsten Bibbins-Domingo, Marshall Stoller, and Thomas L. Chi

OBJECTIVE To determine if limited food access census tracts and food swamp census tracts are associated with increased risk for repeat kidney stone surgery. And to elucidate the relationship between community-level food retail environment relative to community-level income on repeat stone surgery over time.

METHODS Data were abstracted from the University of California, San Francisco Information Commons. Adult patients were included if they underwent at least one urologic stone procedure. Census tracts from available geographical data were mapped using Food Access Research Atlas data from the United States Department of Agriculture Economic Research Service. Kaplan-Meier curves were employed to illustrate time to a second surgical procedure over 5 years, and log-rank tests were used to test for statistically significant differences. A multivariate Cox regression model was used to generate hazard ratios for undergoing second surgery by group.

RESULTS A total of 1496 patients were included in this analysis. Repeat stone surgery occurred in 324 patients. Kaplan-Meier curves demonstrated a statistically significant difference in curves depicting patients living in low income census tracts (LICTs) vs those not living in LICTs (P <.001). On Cox regression models, patients in LICTs had significantly higher risk of undergoing repeat surgery (P = .011). Patients from limited food access census tracts and food swamp census tracts did not have a significantly higher adjusted risk of undergoing second surgery (P = .11 and P = .88, respectively).

CONCLUSION Income more so than food access associates with increased risk of repeat kidney stone surgery. Further research is needed to explore the interaction between low socioeconomic status and kidney stone outcomes. UROLOGY 160: 51−59, 2022.

In the United States, the overall prevalence of kidney stones is estimated to be 9%,[1] but there is growing evidence to suggest that large and complex kidney stone disease is more common in communities of low socioeconomic status (SES). Recent papers have demonstrated that patients from communities of lower SES are more likely to present to care with increased stone burden and stone complexity resulting in a higher need for staged stone procedures.[2,3] Despite these findings, the relationship between low SES and kidney stone disease is not well understood.

There is an intimate relationship between kidney stone disease and diet,[4] and individuals from low SES communities have been shown to have less favorable 24-hour urine parameters suggesting dietary differences in these groups.[3,5] This points to systemic factors specific to low SES communities that influence dietary behavior and result in disparate stone outcomes. It is also known that low-income communities have significantly fewer supermarkets[6] and higher fast food restaurant densities.[7] According to the United States Department of Agriculture (USDA), a limited food access census tract (LFACT) is defined as a census tract where at least 500 people or 33% of the population live greater than 1 mile from a supermarket in urban areas or greater than 10 miles from a supermarket in rural areas.[8] A food swamp census tract (FSCT) is a census tract where unhealthy food sources predominate healthy food sources at a ratio of approximately 4 to 1.[9,10] Here, we investigate the influence of the community retail food environment (LFACTs and FSCTs) on the need for multiple surgeries for kidney stones.

This study aims to determine if LFACTs and FSCTs are associated with increased risk for repeat surgery for kidney

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From the Urology, University of California San Francisco, San Francisco, CA; the University of Central Florida, School of Medicine, Orlando, FL; and the Urology, Emory University, Atlanta, GA

Address correspondence to: David Bayne, M.D., M.P.H., Urology, University of California San Francisco, 400 Parnassus Ave, 6th floor Urology Clinics A638, San Francisco, CA 94143. E-mail: david.bayne@ucsf.edu

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stones. We also aim to determine the relationship between the community-level food retail environment relative to community-level income on repeat kidney stone surgery over time.

METHODS/MATERIALS

Overview

This is a retrospective review of prospectively collected data from Information Commons, a clinical data repository for the University of California, San Francisco (UCSF) Medical Center derived from the electronic health record. De-identified patient data from 2011 to 2020 was included. Patients were followed longitudinally for up to 5 years after their first recorded kidney stone surgery within the repository using an identity-protected patient linkage number.

Data Sources

Data were abstracted from UCSF's Information Commons. The data repository includes clinical characteristics, patient demographic information, medical history in the form of International Classification of Diseases, 10th Revision (ICD-10) diagnostic codes, and surgeries/procedures in the form of Current Procedural Terminology (CPT) codes. This data is regularly collected as part of patient care. The repository was linked to census tract level data through UCSF's Disparities Research: Environment and oMICs (DREAM) lab. Institutional review board approval (IRB) was obtained for this study (IRB #20-31513).

Inclusion and Exclusion Criteria

Adult patients (age 18 or older) were included if they underwent at least one urologic stone procedure, defined by the following CPT codes: Shockwave lithotripsy (SWL) - 50590; Ureteroscopy (URS) - 52320, 52325, 52330, 52352, 52353, 52356; Percutaneous lithotripsy (PNL) - 50060, 50065, 50080, 50081; between 2011 and 2020. To prevent the inclusion of cancer-related urologic procedures, we excluded patients with any documented history of urothelial carcinoma (ICD-10 codes C64-C68). Patients with extremes in body mass indices (BMIs) outside of the 1st to 99th percentile (17-61) were excluded to account for erroneous data collection. Patients with a diagnosis of cystinuria (ICD-10 code E72.01) and primary hyperoxaluria (ICD-10 code E72.53, and R82.992) were also excluded (Fig. 1)

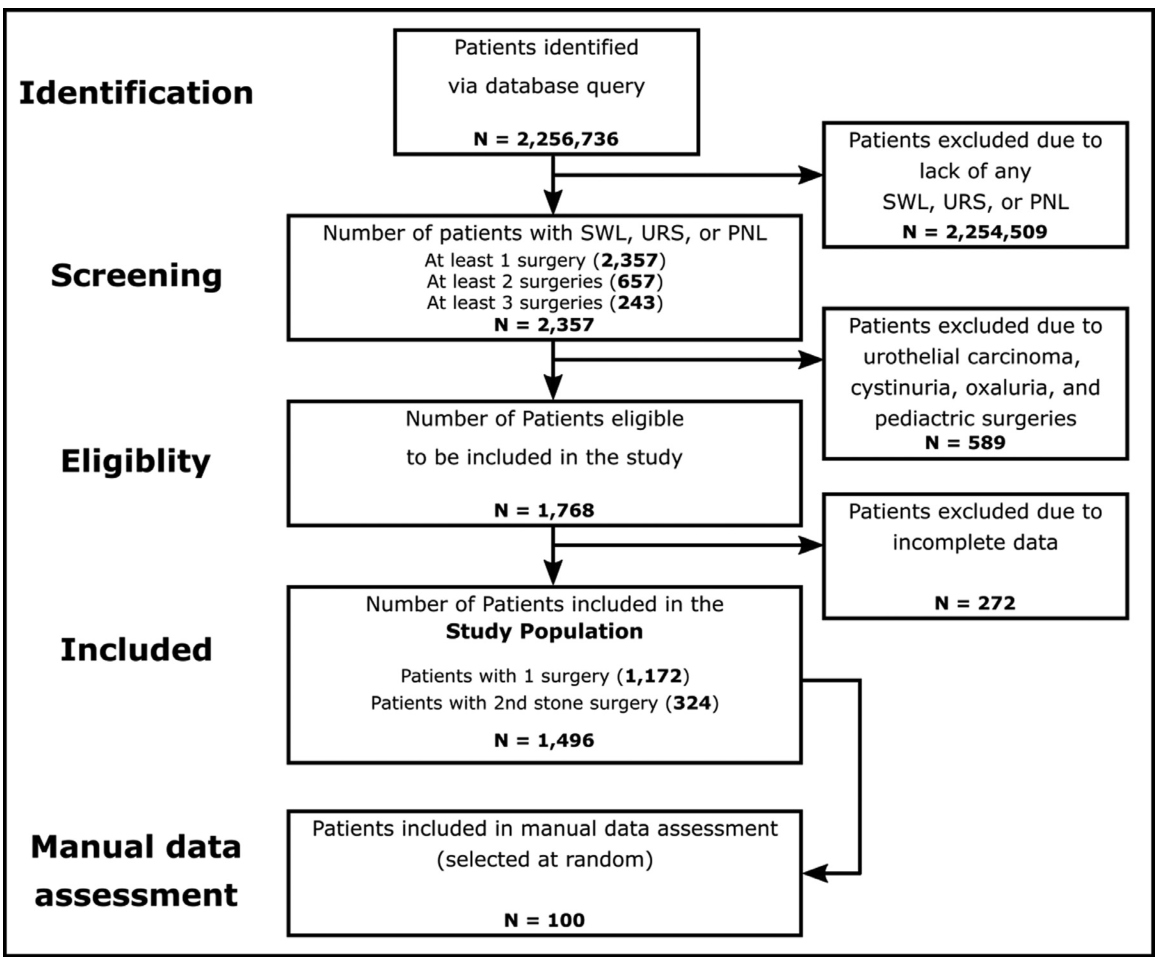


Figure 1. Study population derivation. Query of 2,256,736 records from University of California, San Francisco (UCSF) Electronic Medical Record (EMR) system resulted in 2357 patients with kidney stone surgeries. After applying the inclusion and exclusion criteria, 1172 patients with a single kidney stone surgery and 324 patients with at least 2 kidney stone surgeries were identified as the final study population. One hundred records were then selected at random for manual data assessment to verify the integrity of the data.

to eliminate extreme cases of kidney stone recurrence due to rare genetic factors that may skew surgical frequency patterns of the general stone-forming population.

Covariates

Patient characteristics included age, gender, race, BMI, smoking status, diabetes mellitus, hypertension, health insurance information, smoking history, and race. For this study, race was categorized into the following: White, Black, Asian, Native Hawaiian/Other Pacific Islander, American Indian/Alaskan Native, or other. A diabetes mellitus diagnosis was defined by the presence of ICD-10 codes E08-E11 and E13. For use in our multivariate model, binary variables were created for, gender (male = 1; female = 0), obesity (BMI </= 30 = 0; BMI > 30 = 1), underinsured (Medicaid or indigent care programs = 1; unreported/self-pay, private insurance, Medicare = 0).

Census Tracts and Geographical Data

The census tracts from the available geographical data were mapped using publicly available Food Access Research Atlas data from the USDA Economic Research Service.[8] Elements mapped included: census tracts, population, and median family income. A low-income census tract (LICT) was defined by poverty rates of at least 20% or median family income below the 80th percentile of the metropolitan area or state median income according to USDA standard classifications.[8] LFACT is designated by the USDA standard distance thresholds of greater than 1 mile distance from a supermarket in urban areas and 10 miles distance from a supermarket in rural areas.[8] Census tract was also linked to food retail environment data using the publicly available California Modified Retail Food Environment Index (mRFEI) dataset.[9] Census tracts were categorized as a FSCT if mRFEI exceeded 3.89 based on historical designation.[10]

Cases and Controls

Controls were those patients who underwent an initial stone surgery and did not have a subsequent surgical encounter within a 5 year follow up period. Controls were followed up until the time of their last clinical encounter over the 5 years and considered lost to follow up if their last clinical encounter occurred prior to the end of the 5 year window. Cases were those patients who underwent an initial stone surgery and had a second surgical encounter within a 5 year period after their first surgery. Cases were followed up until the time of their second surgical encounter.

Grouping Based on Time to Second Kidney Stone Surgery

Patients were categorized into five groups based on time to occurrence of second stone surgery. Group one included all patients with any second stone surgery or last clinical follow-up at least 1 day after their first surgery, group two excluded patients with a second surgery or last clinical follow-up within 30 days after their first surgery, group three excluded patients with a second surgery or last clinical follow-up within 180 days after their first surgery, group four excluded patients with a second surgery or last clinical follow-up within 1 year of their first surgery, and group five excluded patients with a second surgery or last clinical follow-up within 3 years after their first surgery. Hazard ratios for undergoing a second surgery was determined in each group.

Statistical Analysis

All univariate tests were performed with a Chi-squared test for categorical variables and Student's t-test for continuous variables. Kaplan-Meier curves were employed to illustrate time to a second surgical procedure for kidney stones. A log-rank test was used to test for statistically significant differences in the Kaplan-Meier curves. A cox-proportional hazards model with and without covariates was used to account for confounded association with covariates. All data analyses were conducted using R version 4.0.

Data Fidelity Assessment

To assess data fidelity, IRB approval was obtained to unmask 100 patient entries from structured data and manual electronic medical record data abstraction was performed. Data was abstracted through the review of scanned clinical documents from outside institutions and Care Everywhere documentation to determine if there was an outside surgery performed within the 5-year follow up window after the patient's initial stone surgery at UCSF. Care Everywhere is a high fidelity health Information exchange system that allows for automated exchange of health care information for institutions using EPIC electronic health record systems.[11,12] Verification of past medical history also was undertaken to confirm absence of urothelial carcinoma and cystinuria diagnoses for each unmasked patient.

RESULTS

A total of 1496 patients were included in the study population. Repeat kidney stone surgery occurred in 324 patients (Fig. 1). Patient characteristics are summarized and compared in Table 1. There were no differences in gender, smoking history, race, age, diabetes frequency, hypertension frequency, or insurance type between those who did and did not undergo repeat stone surgery during the study period. Patients who underwent repeat stone surgery had a higher average BMI (29.8 vs 28.8, P = .044) (Table 1). Both PNL and SWL were more common in patients who went on to have a second surgery for kidney stones (Table 1). Frequency of having a second stone surgery was more common among patients with home addresses in LICTs (P = .0071) but not among individuals with home addresses in LFACTs or FSCTs (Table 1).

Kaplan-Meier curves depicting probability of having a second surgery for kidney stones over the time span of 5 years were stratified by residence in LFACTs, FSCTs, and LICTs and are shown in Figure 2. No significant difference was observed in LFACTs compared to non LFACTs (P = .15, Fig. 2A) and FSCTs compared to non FSCTs (P = .84, Fig. 2B), but a statistically significant difference was observed in curves depicting patients living in LICTs vs those not living in LICTs (P <.001, Fig. 2C).

A multivariate Cox regression model was generated and the hazard ratios (HR) are summarized in Table 2. When adjusting for all other factors (food environment, age, gender, race, obesity, surgery type, diabetes, hypertension, and insurance type) patients from LICTs had significantly higher risk of undergoing a repeat stone surgery (HR = 1.36 [1.07-1.71], P = .011; Table 2). This translated to approximately 36% increased risk of second surgery within a 5 year period following first surgery. Patients from census tracts defined as LFACTs and FSCTs did not have a significantly higher adjusted risk of undergoing a second surgery for stones (HR = 1.25 [0.95-1.63], P = .11, and 1.02 [0.81-1.28], P = .88, respectively; Table 2). Adjusted The HR for repeat

Table 1. Patient characteristics. Univariate analysis comparing differences between cases and controls of the study population

	2nd Stone Surgery		
	Yes	No	*P*-value
N	324	1172	
Gender			.11
Male	153 (47.2%)	615 (52.5%)	
Female	171 (52.8%)	557 (47.5%)	
Smoking status			.86
Former/Current smoker	127 (39.2%)	468 (39.9%)	
Never smoker	197 (60.8%)	704 (60.1%)	
Race			.47
White or Caucasian	198 (61.1%)	699 (59.6%)	
Asian	42 (13.0%)	175 (14.9%)	
Black or African American	19 (5.9%)	49 (4.2%)	
Other	65 (20.1%)	249 (21.2%)	
BMI (mean, sd)	29.8, 7.9	28.8, 7.1	.044*
Age at first surgery (mean, sd)	53.8, 15.0	54.5, 15.5	.47
Surgery type at first encounter			<.001*
PNL	139 (42.9%)	426 (36.3%)	
URS	155 (47.8%)	691 (59.0%)	
SWL	30 (9.3%)	55 (4.7%)	
Diabetes	88 (27.2%)	283 (24.1%)	.30
Hypertension	166 (51.2%)	536 (45.7%)	.090
Insurance type			.098
Insured	232 (71.6%)	894 (76.3%)	
Under-insured	92 (28.4%)	278 (23.7%)	
LICT	143 (44.1%)	419 (35.8%)	.0071*
LFACT	75 (23.1%)	230 (19.6%)	.19
FSCT	188 (59.1%)	687 (59.4%)	.99

BMI, body mass index; FSCT, food swamp census tract; LFACT, low food access census tract; LICT, low income census tract; PNL, percutaneous lithotripsy; SWL, shockwave lithotripsy; URS, ureteroscopy.
Food swamp data was available for 1475 (98.6%) patients.
* *P* <.05.

stone surgery was higher for patients who initially underwent SWL (2.27 [1.52-3.39], *P* <.001) and PNL (1.52 [1.19-1.93], *P* <.001) relative to URS (Table 2).

LFACTs and FSCTs were not associated with statistically significant higher risk of repeat surgery at any time within 5 years after initial stone surgery when controlling for LICTs (*P* >.05). This lack of significance persisted when excluding surgeries within 30 days, 180 days, 1 year, or 3 years after initial stone surgery. When looking at time to repeat stone surgery and when controlling for LFACTs or FSCTs, LICTs were associated with a statistically significant higher risk of second surgery at any time within 5 years after initial stone surgery. However, this higher risk was no longer statistically significant when surgeries occurring less than 180 days after the initial surgical procedure were excluded from the analysis (Supplementary Table 1).

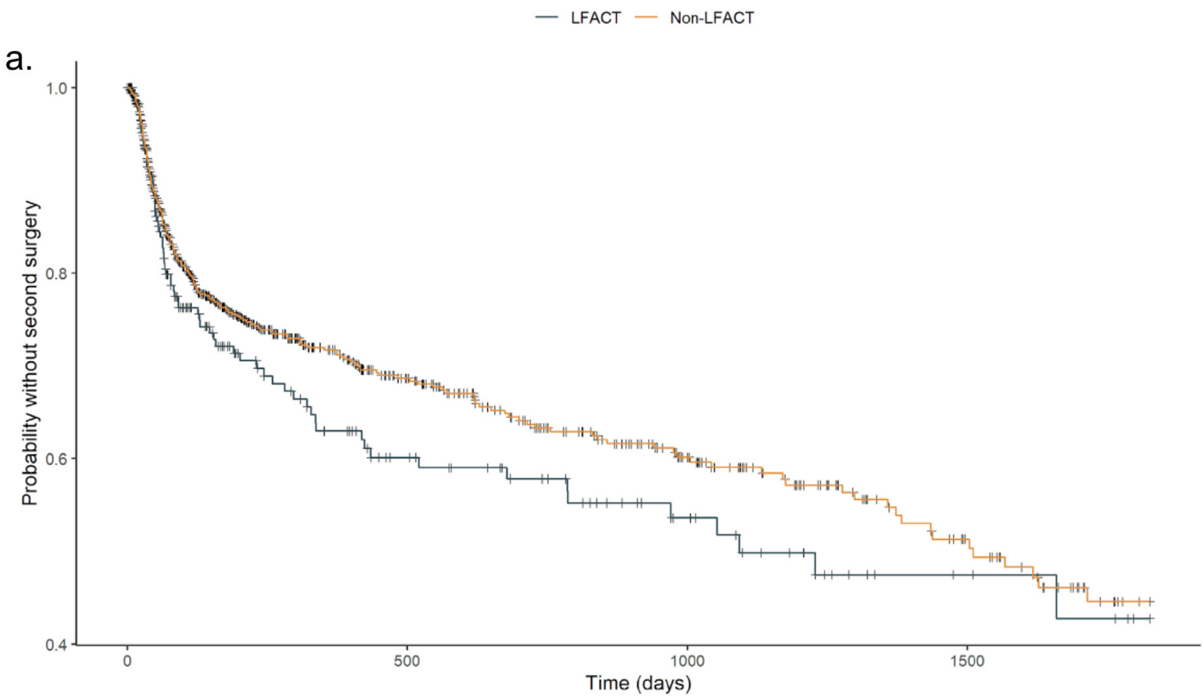
Manual data assessment of a subset of 100 randomly unblinded patient records revealed that only one patient underwent kidney stone surgery outside of UCSF within 5 years of their initial UCSF surgery. In this subset, all patients were confirmed to not have cystinuria or urothelial carcinoma, verifying fidelity to our exclusion criteria for these data points by 100%.

DISCUSSION

In this paper we demonstrate that among patients undergoing kidney stone surgery between 2011 and 2020 at UCSF, individuals with home addresses within LFACTs and FSCTs did not have higher frequency of repeat surgery for kidney stones. However, individuals in LICTs had higher frequency of repeat surgery even when controlling for LFACTs, FSCTs, and individual-level patient factors including age, gender, race, diabetes, obesity, procedure type, and insurance status. To our knowledge this is the first study to compare the impact of community-level income and community-level retail food environment on operative stone recurrence.

Interestingly, patients with home addresses in LICTs experienced reduced time to second surgery after initial operative treatment (*P* <.001). When controlling for food environment, the increased risk for repeat stone surgery that was associated with LICTs did not persist when only considering repeat procedures occurring greater than 180 days after the first surgery (Supplementary Table 1). This may be due to loss of follow up causing reduction in sample size and therefore reduction in statistical power as time from initial stone surgery increases. This may also suggest that LICTs predict increased risk of second stone surgery due to more advanced disease at presentation resulting in residual stone burden (need for staged procedures for a very large solitary stone or particularly complex stone burden, for example), rather than a newly formed stone. It is possible that patients from LICTs have less access to regular medical care, including metabolic evaluations for stones (ie 24-hour urine collection), resulting in later presentation and greater stone burden. These patients with advanced disease may, then, be at higher risk of requiring more extensive treatment and multiple procedures to adequately clear their stones. This, perhaps, explains why, when controlling for other covariates, patients undergoing PNLs for their first surgery had a higher rate of second procedures for stones (1.52 [1.19-1.93], *P* <.001) relative to patients who underwent URS as their first surgery. It is possible that patients undergoing PNL initially also had a higher frequency of large or complex stones requiring staged procedures. We also found that, when controlling for other covariates, patients who underwent SWL as their first kidney stone surgery were more at risk for needing a second stone surgery (2.27 [1.52-3.39], *P* <.001) relative to patients undergoing URS. This is consistent with a known lower stone clearance rate for SWL relative to URS.[13,14]

Individuals living in LFACTs and FSCTs have higher rates of obesity than individuals not living in these areas.[15,16] Hospitalization rates for diabetes are higher among individuals living in FSCTs.[17] Despite these findings, there are persistent gaps in knowledge in our understanding of the relationship between the food retail environment and health outcomes. Some studies have shown that income impacts health outcomes more so than food access or unhealthy food retail density. For example, outcomes for diabetes have been shown to be more dependent on food insecurity, which is a measurement of financial capacity to purchase food, rather than food proximity.[18] Although outcomes for cardiovascular disease (another disease influenced by dietary behavior[19]) are worse in LFACTs, census tract income rather than food access is the key determining factor.[20] Consequently, there is doubt as to whether or not actual dietary behavior is linked to the surrounding retail food environment. It is also possible that other factors associated with low SES communities beyond dietary behavior impact health outcomes. It is important to note that diseases that predispose to kidney stone formation such as obesity[21] and diabetes[22] are more common in low SES populations.[23] However, even when controlling for obesity, diabetes, and other factors such as gender, race, health insurance, and surgical

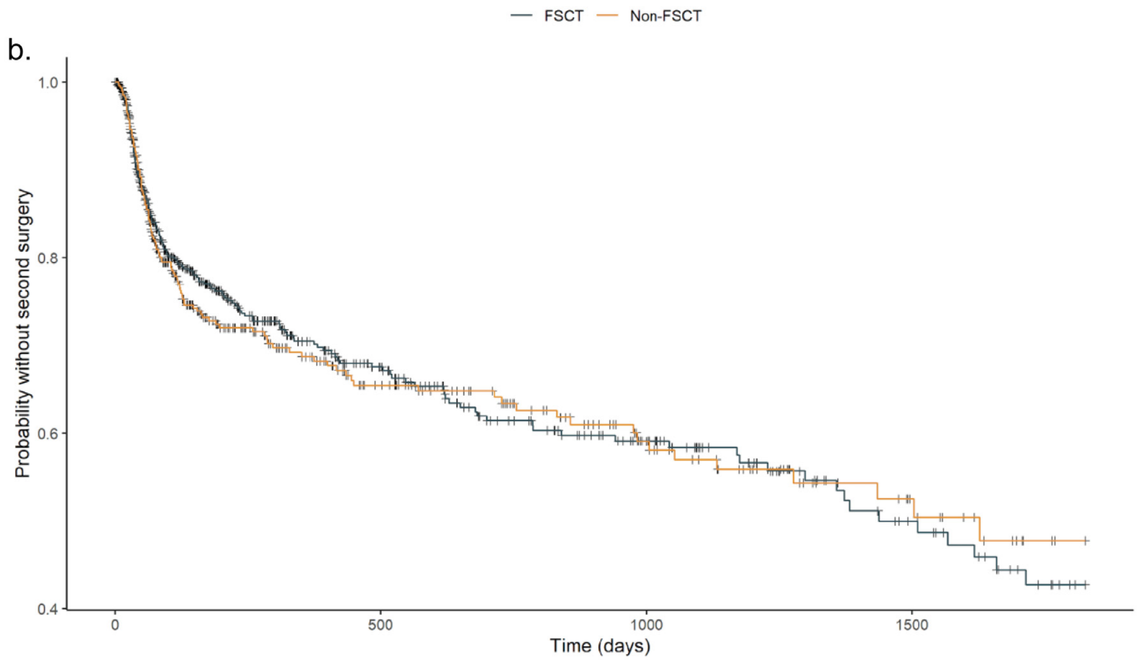


	0	500	1000	1500
Low Food Access Census Tract (LFACT)	305 (57)	57 (125)	32 (20)	12 (17)
Non-Low Food Access Census Tract (Non-LFACT)	1191 (172)	220 (590)	117 (82)	53 (51)

N at risk (N censored)

P-value = 0.15

Figure 2. Kaplan Meier estimates for: (**A**) Low Food Access Census Tracts (LFACT), (**B**) Food Swamp Census Tracts (FSCT), and (**C**) Low Income Census Tracts (LICT). The x axis is time in days from the first surgery for kidney stones. The y axis is the probability of not having a second stone surgery. (**A**) The blue curve represents individuals living in LFACTs and the yellow curve represents individuals not living in LFACTs. *P* value was calculated using log-rank test. (**B**) The blue curve represents individuals living in FSCTs and the yellow curve represents individuals not living in FSCTs. *P* value was calculated using log-rank test. (**C**) The blue curve represents individuals living in LICTs and the yellow curve represents individuals not living in LICTs. *P* value was calculated using log-rank test. (Color version available online.)



	0	500	1000	1500
Food Swamp Census Tract (FSCT)	875 (126)	162 (430)	85 (60)	39 (37)
Non-Food Swamp Census Tract (Non-FSCT)	600 (98)	110 (267)	61 (42)	25 (30)

N at risk (N censored)

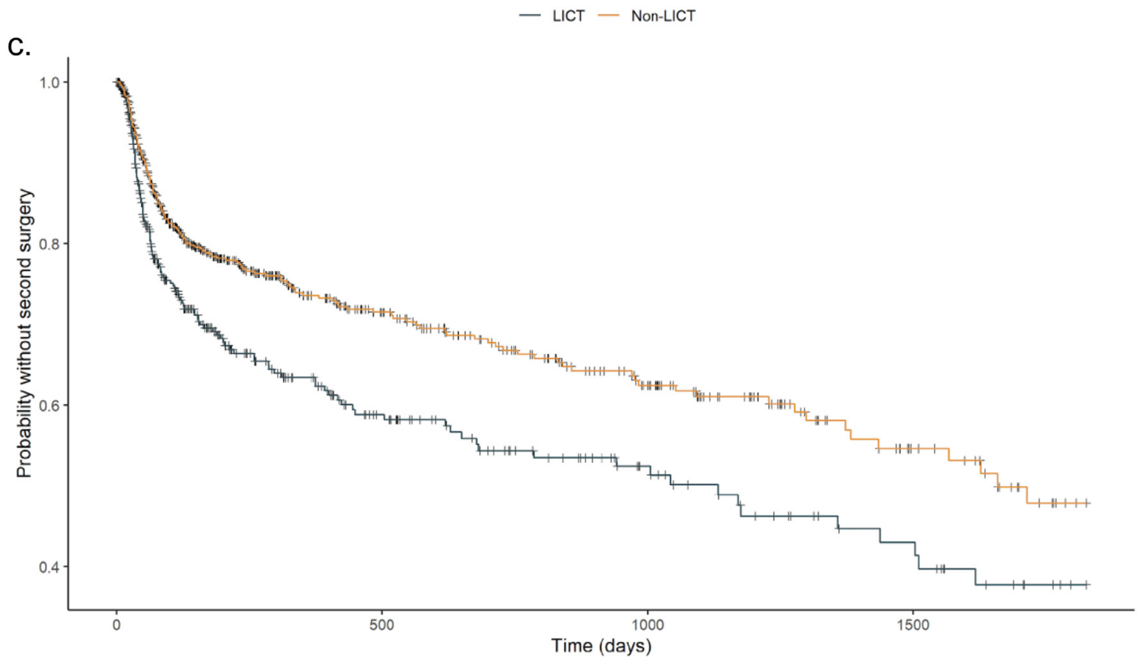
P-value = 0.84

Figure 2. Continued

procedure type, living in a LICT predicted for higher risk for second surgery while living in a LFACT and FSCT did not.

Limitations

This study is limited in that the data utilized is from a single academic center located in San Francisco, California. Consequently, the patient population in this study may not be representative of the common urology patient, and the community-level covariates included in our analysis may not account for unique factors specific to the region that differ from the typical community-level factors affecting stone outcomes on a national scale. As a tertiary care center there are many patients referred for complex care and many patients that are lost to follow up early on after surgery as they return to their local urologists. This is reflected in the large quantity of censored patients early on in our Kaplan-Meier curves (Figs. 2A-2C). To account for this and to rule out the possibility that a large percentage of patients who do not follow up at our center are undergoing additional kidney stone procedures at outside facilities, we examined the frequency at which a subset of 100 randomly selected patients underwent surgery outside of UCSF. We manually abstracted data from outside scanned notes in the electronic health record and Care Everywhere documentation that are not included in the UCSF Information Commons database. Out of this randomly selected subset of patients, the rate of outside surgery after initial UCSF surgery was 1%. Nevertheless, we may be missing follow up encounters not included in these additional records. This study is also limited by sample size and because of this we are not able to study the combined effect of living in a LICT and a FSCT or LFACT. Assessing the effect of LICTs on stone persistence (residual stone burden after surgery) vs stone



	0	500	1000	1500
Low Income Census Tract (LICT)	562 (98)	91 (248)	47 (36)	26 (14)
Non-Low Income Census Tract (Non-LICT)	943 (131)	186 (467)	102 (66)	39 (54)

N at risk (N censored)

P-value < 0.001

Figure 2. Continued

recurrence (newly formed stone) was limited due to decrease in statistical power attributed to decreasing sample size over time. With larger sample size we may have been able to better assess differences in insurance type and frequency of multiple surgeries. We also do not have data on the laterality of kidney stone surgery. Additionally, we could not definitively determine whether repeat surgeries represented persistence or recurrence. However the short span of time between the bulk of procedures suggests that persistence is more likely. Therefore, while we have enough evidence to suggest an effect of LICTs on stone persistence, studies with larger datasets are needed to further evaluate the effect of LICTs on long-term stone recurrence. Another potential limitation of this study is that it does not account for potential change in census tract income and food access status over time. However, the USDA has demonstrated only small changes in low income and low access areas from 2010 to 2015, suggesting a very slow rate of change over time.[24]

These findings add to the growing body of literature linking community SES and kidney stone disease outcomes. There are multiple factors that influence health outcomes in disadvantaged communities.[25,26] Given the established relationship between diet and kidney stones,[4] it is logical to conclude that regional food retail environments contribute to disparate stone outcomes in low-income communities. However, even though the food retail environment has demonstrated associations with consumer food purchases and health outcomes[27] improved access to healthy food alone does not directly change dietary behaviors.[28] Our study findings may be explained by the possibility that dietary behavior is more determined by income than by the food retail environment, patients travel beyond their census tract for food purchases, and/or

Table 2. Hazard ratio estimated from fully adjusted cox-regression model. Hazard ratios depict adjusted risk for repeat kidney stone surgery within 5 years of initial kidney stone surgery date

N = 1487	HR	95% Confidence Interval	*P*-value
LICT	1.36	1.07-1.71	.011*
LFACT	1.25	0.95-1.63	.11
FSCT	1.02	0.81-1.28	.88
Age	1.00	0.99-1.01	.74
Gender			
Male	0.82	0.65-1.04	.10
Female	Ref	Ref	Ref
Race			
Asian	0.80	0.56-1.14	.22
Black or African American	1.14	0.70-1.84	.61
Other	0.91	0.67-1.23	.53
White or Caucasian	Ref	Ref	Ref
Obesity	1.12	0.88-1.43	.36
Surgery type at first encounter			
SWL	2.27	1.52-3.39	<.001*
PNL	1.52	1.19-1.93	<.001*
URS	Ref	Ref	Ref
Diabetes	1.08	0.83-1.42	.55
Hypertension	1.04	0.81-1.33	.75
Insurance type			
Underinsured	1.22	0.93-1.61	.16
Insured	Ref	Ref	Ref

Food swamp data was available for 1475 (98.6%) patients.
* $P < .05$.

that there are additional factors that negatively impact stone outcomes in low-income communities. Indeed, individuals with lower income are less likely to have access to specialty care,[29] and are more likely to forgo care due to cost.[30] These differences create obstacles in the diagnosis and treatment of kidney stones for low SES patients that extend beyond proximity to healthy food retailers.

CONCLUSION

Individuals from low-income census tracts treated in our academic tertiary stone referral center were more likely to require repeat stone surgery while census tract food retail environment did not affect risk for repeat surgery. This study adds to the growing body of knowledge linking low SES and disparate kidney stone outcomes. These disparities may be a result of systemic obstacles that extend beyond proximity to healthy food retailers. Nevertheless, more investigation is needed to explore the relationship between community income and kidney stone disease.

SUPPLEMENTARY MATERIALS

Supplementary material associated with this article can be found in the online version at https://doi.org/10.1016/j.urology.2021.11.010.

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