Received: 12 April 2021 | Revised: 9 September 2021 | Accepted: 20 September 2021
DOI: 10.1002/rth2.12605

ORIGINAL ARTICLE

Association between transportation barriers and anticoagulation control among an inner-city, low-income population: A prospective observational cohort study

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Funding information
Partial funding for this work was provided by the University of Illinois at Chicago, College of Pharmacy, Office of the Dean, David J. Riback Research Fellowship. The project described was supported by the National Center for Advancing Translational Sciences, National Institutes of Health, through Grant UL1TR002003. The content is solely the responsibility of the authors and does not necessarily represent the official views of the National Institutes of Health.

Handling Editor: Dr Suzanne Cannegieter.

Abstract

Background: Anticoagulation with warfarin represents a transportation-sensitive treatment state. Transportation barrier is a common reason for not using health care services.

Objective: To assess the association between transportation barriers to anticoagulation clinic and anticoagulation control (AC) among an inner-city, low-income population.

Patients/Methods: Adults expected to be on chronic warfarin therapy were recruited from an ambulatory anticoagulation clinic. Participants completed a validated questionnaire that assessed transportation barriers to clinic, defined as self-reported trouble getting transportation to a clinic and a composite score of the presence of transportation barriers. Suboptimal AC was defined as time in therapeutic range (TTR) <60% over 6 months. Prevalence ratios with 95% confidence intervals (CIs), adjusted for age, sex, and annual household income, described the association of transportation trouble and barriers with AC.

Results: Of 133 participants, 42.9% had suboptimal AC. Mean age was 60.4 (SD, 13.6) years, and the majority of participants were women (62.2%). Participants with transportation trouble were more likely to report being disabled/unable to work (63.6%) and annual household income <$15 000 (45.5%). Mean TTR was significantly lower for participants with transportation trouble compared to those without (53.8% [SD, 24.7%] vs 64.7% [SD, 25.0%]; $P = .03$). Participants reporting transportation trouble or at least one transportation barrier were 1.60 (95% CI, 1.07-2.39) and 1.68 (95% CI, 1.01-2.80) times more likely, respectively, to have suboptimal AC compared to those without.

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Conclusion: Inner-city, low-income individuals with transportation barriers were more likely to have suboptimal AC. Further research is warranted to evaluate the impact of alleviating patient-specific transportation barriers on anticoagulation outcomes.

KEYWORDS
anticoagulants, health outcome, health care services, transportation, warfarin

Essentials

- Associations between transportation barriers and patients' anticoagulation outcomes are unknown.
- We conducted a cohort study of patients on chronic warfarin and managed at an urban anticoagulation clinic.
- Patients with transportation barriers are more likely to have poor anticoagulation control.
- It is important to screen and identify patients at high risk for transportation barriers.

1 | INTRODUCTION

Transportation is a major barrier to timely access to medical care and medications.[1] In 2017, ≈5.8 million Americans missed or delayed medical care due to transportation issues.[2,3] While specific transportation issues vary by geographic location (ie, rural vs urban), commonly reported travel barriers included lack of access to transportation (eg, vehicle, bus), associated cost, transport reliability, and commute safety (Figure 1). Transportation barriers may particularly impact the elderly, low-income individuals, or those residing further from health care providers.[1,2,4-7]

By missing medical appointments, patients are denied opportunities for assessment of medical conditions, adjustments to treatment, and escalation or deescalation of care.[1,8] Although not all missed health care visits adversely impact health outcomes equally, evidence shows that missed medical appointments have been associated with increased emergency department visits, hospitalizations, and premature mortality.[1,9,10] Patients with vehicle ownership and higher Medicaid reimbursement for transportation had increased health care usage compared to those without.[1] Among low-income individuals, patients taking public transportation were twice as likely to miss their medical appointment compared to patients with private transportation.[11] Urban patients who used public transportation or walked to their hospital were less likely to have regular health care visits and more likely to delay care.[12]

Anticoagulation with warfarin represents a transportation-sensitive treatment state. Use of warfarin is limited by its narrow therapeutic index, major drug interactions, and variability in dose requirements.[13-15] Thus, warfarin therapy requires close monitoring of international normalized ratio (INR) and dose adjustment to ensure appropriate titration. The frequency of clinic visits to monitor warfarin dosing requirements vary by patient, but even stable patients typically require monthly visits for monitoring checks. Pharmacist-led anticoagulation services have improved health care costs by lowering the frequency of thromboembolic and bleeding events, hospitalizations, and emergency department visits.[16] However, clinic no-shows remain an issue. To our knowledge, no published studies to date have examined the effects of transportation barriers on anticoagulation clinic attendance or associated patient health outcomes.[1,17] This study aimed to address this gap by exploring the relationship between transportation to an anticoagulation clinic for warfarin monitoring and the level of anticoagulation control (AC) among an inner-city, low-income population.

2 | METHODS

2.1 | Study design and study population

A prospective observational cohort study was conducted at a pharmacist-led antithrombosis clinic (ATC) located at an urban academic health care system in Chicago, Illinois. The ATC provided care for >500 patients treated with warfarin, among whom most were marginalized individuals due to race/ethnicity or socioeconomic background. Clinical pharmacists worked under a collaborative practice arrangement with physicians to manage, initiate, and monitor antithrombotic therapies. Pharmacists documented clinic encounters and tracked missed clinic appointments in the electronic medical record (EMR) as part of usual care.

Participants were recruited during their regularly scheduled appointments at the ATC between June 25, 2018, to October 16, 2018. Two trained research assistants (RAs) prescreened scheduled patients for eligibility using the EMR. Eligible patients were approached in the ATC to assess their interest and confirm eligibility. RAs tracked eligible patients who missed their regularly scheduled appointment during the recruitment period and attempted to recruit them at subsequent scheduled appointments. Eligible participants were ≥21 years old, on established anticoagulation management at the ATC, taking warfarin for at least 3 months at time of enrollment, expected to remain on warfarin therapy for at least 6 months after enrollment, and English speaking. Exclusion criteria included terminal illness with <6 months life expectancy at time of enrollment; dementia or other serious cognitive impairment; legally blind, hearing impaired, or deaf; or serious mental impairment (eg, schizophrenia, bipolar disorder).

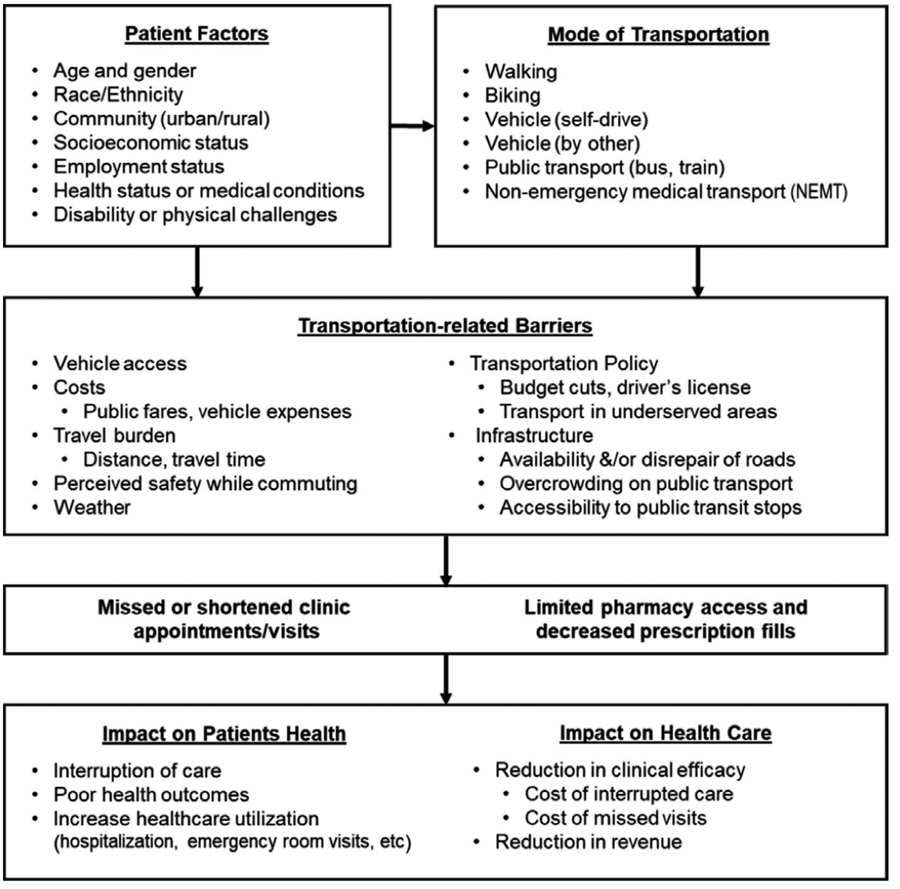

FIGURE 1 Conceptual framework: Transportation impact on health outcomes

Written informed consent and Health Insurance Portability and Accountability Act authorization were obtained from all participants before completing the one-time questionnaire administered by the RAs. All patient/personal identifiers were removed or disguised so the patient/person(s) described are not identifiable and cannot be identified through the details of the study. Compensation of $10 cash was provided at completion of the questionnaire. This study had full approval by the University of Illinois at Chicago's institutional review board.

2.2 | Transportation measures

Transportation barriers were measured using a modified version of a 14-item validated questionnaire that captures mode of transportation options specific to urban environments and associated barriers.[18] Two scores resulted. The first reflected the amount of trouble associated with getting transportation to the ATC. In the original questionnaire, the item on transportation trouble had four response choices. Authors conducted a Rasch category function analysis that supported the use of a three-point scale (no trouble, some trouble, a lot of trouble). Due to small sample sizes, we dichotomized this for analyses (no trouble vs some/a lot of trouble). The second was a summary score (0-5) of five dichotomous items: being delayed, late or missing an appointment due to transportation, impact of transportation costs, physical challenges, perceived safety while commuting, and impact of weather on travel. A score of ≥1 classified participants as having a transportation barrier to clinic. Two open-ended items asked patients to self-report their approximate travel time in minutes from residence to ATC and approximate round-trip travel costs. An objective measure of travel distances was calculated using self-reported residential and ATC addresses. The SAS (SAS Institute, Cary, NC, USA) GEOCODE procedure, which identified longitude and latitude coordinates, determined the geodetic or straight line distances (ie, distance between two points along the earth's surface) in miles.[19,20]

2.3 | Anticoagulation outcome

Participants' warfarin laboratory values (eg, INR) were abstracted from the EMR during the 6-month follow-up period. AC was measured as percentage of time in therapeutic range (TTR) and calculated using the Rosendaal linear interpolation method.[21] A minimum of two reported INRs were needed to calculate the TTR. Suboptimal AC was defined as a TTR <60%; TTR ≥60% was considered optimal AC. Previous literature has reported a TTR <60% as clinically inefficient warfarin therapy or limited treatment benefit to patients.[22,23] Participants who discontinued warfarin therapy during follow-up were excluded from analysis.

2.4 | Covariates

Participants' sociodemographic characteristics (eg, age, sex, race/ethnicity), and medical information (eg, vitamin K intake, smoking history, alcohol intake, marijuana use) were self-reported. Patients' health literacy was measured using the 36-item Short Test of Functional Health Literacy in Adults and categorized as three levels: 0 to 16, inadequate; 17 to 22, marginal; and 23 to 36, adequate.[24] Due to small cell sizes, inadequate and marginal health literacy were combined into one category. Baseline clinical information (eg, comorbidities, laboratory values) were abstracted from the EMR at the date closest to study enrollment. Comorbidities were used to calculate the Charlson Comorbidity Index and categorized as follows: 0, no comorbidity; 1 to 2, mild comorbidity; 3 to 4, moderate comorbidity; and ≥5, severe comorbidity.[25] Based on participants' indication for warfarin therapy, the following risk factors were calculated: risk of stroke in atrial fibrillation using the $CHAD_2DS_2$-VASc, risk of recurrent venous thromboembolism using the Disability of the Arm, Shoulder, and Hand score, and outpatient bleeding risk index. All data were recorded into Research Electronic Data Capture.[26]

2.5 | Statistical analysis

Descriptive statistics were calculated for sociodemographics, clinical characteristics, and travel parameters. Group differences were assessed using student *t* tests for continuous variables, and chi-square or Fisher's exact test for categorical variables, at a significance level of 0.05.

Log-binomial models were used to estimate prevalence ratios with 95% confidence intervals (CIs) to assess the impact of trouble getting transportation to a clinic and presence of transportation barriers on AC. When log-binomial models failed to converge, Poisson regressions with robust variance were used.[27] Two minimally adjusted models were selected a priori: model 1, adjusted by age and sex; and model 2, adjusted by annual household income. Fully adjusted models were adjusted by age, sex, and annual household income, which were selected a priori and based on a backward selection approach. Statistical analyses were conducted using SAS version 9.4 (SAS Institute).[28]

2.6 | Sensitivity analysis

In the sensitivity analysis, the optimal AC threshold was varied from 60% to 50%, 55%, 65%, and 70% TTR. These TTR thresholds also reflect the range of TTR ranges reported in other studies.[22] As the Rosendaal method may overestimate anticoagulation control, percent time in INR range was calculated as follows: the number of INR values within participants' respective INR goals (eg, INR, 2-3) over the 6-month period divided by the total number of INR values reported over the same period.[29] Optimal AC thresholds were the same as the main analyses (eg, variation from 50% to 70%). Sensitivity analyses were conducted by log-binomial and Poisson regression models adjusted by age, sex, and annual household income.

3 | RESULTS

In total, 144 participants provided consent and completed the questionnaire (Figure 2). Eleven participants stopped warfarin therapy during the 6-month follow-up and were excluded from analysis. Final analysis included 133 participants.

The majority of participants were African American (71.4%) and women (62.2%), with mean age of 60.4 (SD, 13.6) years (Table 1). Mean duration of warfarin therapy was 78.5 (SD, 72.2) months, or ≈6.5 years. During the 6-month follow-up, participants on average

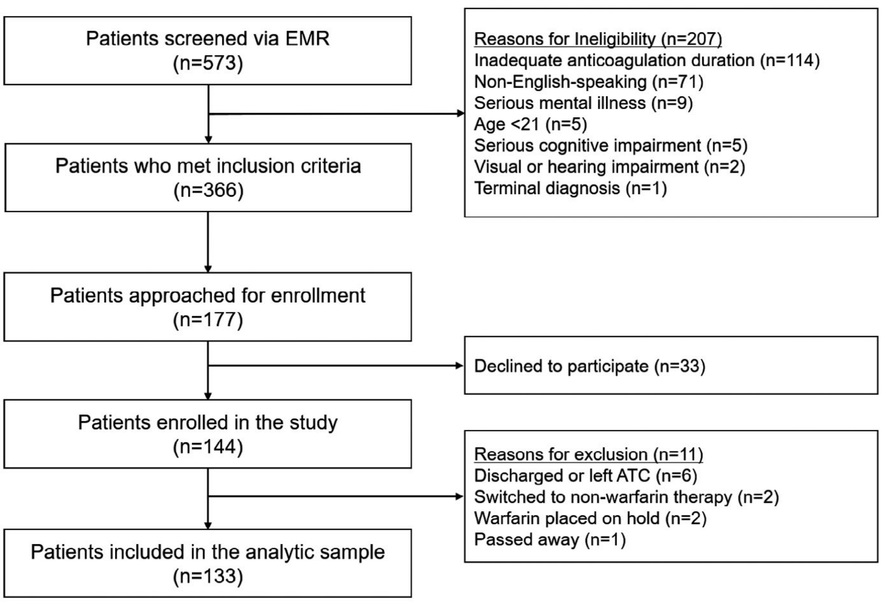

FIGURE 2 Study flow diagram

TABLE 1 Baseline demographics and clinical characteristics by trouble getting transportation to a clinic

Characteristics	Overall n = 133	No trouble getting transportation to clinic n = 100	Trouble getting transportation to clinic n = 33
Age, y, mean (SD)	60.4 (13.6)	60.7 (14.0)	59.4 (12.1)
Race/Ethnicity, n (%) (Other: n=10)			
Black or African American	95 (71.4)	70 (70.0)	25 (75.8)
Hispanic or Latino	15 (11.3)	10 (10.0)	5 (15.2)
White	13 (9.8)	11 (11.0)	2 (6.1)
Female, n (%)	84 (63.2)	65 (65.0)	19 (57.6)
Marital status, n (%)			
Single, never married	53 (39.8)	39 (39.0)	14 (42.4)
Married or living with partner	40 (30.1)	31 (31.0)	9 (27.3)
Widowed, divorced, or separated	40 (30.1)	30 (30.0)	10 (30.3)
Education, n (%) (Other: n=1)			
Less than high school	19 (14.3)	11 (11.0)	8 (24.2)
High school diploma/GED	58 (43.6)	45 (45.0)	13 (39.4)
Associate/Certificate/College degree or above	55 (41.4)	43 (43.0)	12 (36.4)
Employment status, n (%) (Other: n=7)			
Employed for wages full time or part time	25 (18.8)	22 (22.0)	3 (9.1)
Unemployed	19 (14.3)	16 (16.0)	3 (9.1)
Retired	36 (27.1)	31 (31.0)	5 (15.2)
Disabled and unable to work	46 (34.6)	25 (25.0)	21 (63.6)
Annual household income, n (%)			
Refused to answer	10 (7.5)	6 (6.0)	4 (12.1)
<$15 000	41 (30.8)	26 (26.0)	15 (45.5)
$15 000-$25 000	26 (19.5)	17 (17.0)	9 (27.3)
$25,000 $75 000	41 (30.8)	37 (37.0)	4 (12.1)
>$75 000	14 (10.5)	13 (13.0)	1 (3.0)
Insurance, n (%)			
PPO/HMO	34 (25.6)	29 (29.0)	5 (15.2)
Medicare	40 (30.1)	31 (31.0)	9 (27.3)
Medicaid	35 (26.3)	26 (26.0)	9 (27.3)
Medicare and Medicaid	24 (18.0)	14 (14.0)	10 (30.3)
Self-reported general health status, n (%)			
Excellent/Very good	22 (16.5)	22 (22.0)	0 (0.0)
Good	49 (36.8)	38 (38.0)	11 (33.3)
Fair/poor	62 (46.6)	40 (40.0)	22 (66.7)
Health literacy, n (%)[a]			
Inadequate/Marginal (0-22)	35 (26.7)	27 (27.3)	8 (25.0)
Adequate (23-36)	96 (73.3)	72 (72.7)	24 (75.0)
Vitamin K in diet, n (%)	107 (80.5)	81 (81.0)	26 (78.8)
Marijuana use, n (%)	5 (3.8)	4 (4.0)	1 (3.0)
Alcohol use frequency, n (%)			
Never	85 (63.9)	59 (59.0)	26 (78.8)
Monthly or less	28 (21.1)	21 (21.0)	7 (21.2)
2-4 times/mo	15 (11.3)	15 (15.0)	0 (0.0)

TABLE 1 (Continued)

Characteristics	Overall n = 133	No trouble getting transportation to clinic n = 100	Trouble getting transportation to clinic n = 33
≥2-3 times/wk	5 (3.8)	5 (5.0)	0 (0.0)
Smoking frequency, n (%)			
Never	119 (89.5)	88 (88.0)	31 (93.9)
≤2-4 time/mo	2 (1.5)	2 (2.0)	0 (0.0)
≥2-3 times/wk	12 (9.0)	10 (10.0)	2 (6.1)
Charlson Comorbidity Index, mean (SD)	3.5 (2.1)	3.3 (2.1)	4.0 (2.1)
Charlson Comorbidity Index, n (%)			
No comorbidity (0)	7 (5.3)	7 (7.0)	0 (0.0)
Mild comorbidity (1-2)	43 (32.3	34 (34.0)	9 (27.3)
Moderate comorbidity (3-4)	43 (32.3%)	31 (31.0)	12 (36.4)
Severe comorbidity (≥5)	40 (30.1)	28 (28.0)	12 (36.4)
Number of prescription medications, mean (SD)	10.8 (5.3)	9.8 (5.0)	13.9 (5.2)
Number of OTC medications, mean (SD)	1.5 (1.6)	1.5 (1.5)	1.6 (1.7)
Warfarin indication, n (%)			
Atrial fibrillation	24 (18.0)	17 (17.0)	7 (21.2)
VTE (DVT/PE)	57 (42.9	44 (44.0)	13 (39.4)
Heart valve replacement	4 (3.0)	3 (3.0)	1 (3.0)
Other indications[b]	48 (36.1)	36 (36.0)	12 (36.4)
Goal INR 2-3, n (%)	115(86.5)	87 (87.0)	28 (84.8)
Length of warfarin therapy, mo, mean (SD)	78.5 (72.2)	82.5 (74.6)	66.4 (63.7)
$CHAD_2DS_2$-VASc score, mean (SD)[c]	3.5 (1.5)	3.3 (1.3)	3.9 (1.9)
DASH score for recurrent VTE, mean (SD)[d]	0.8 (1.0)	0.9 (1.0)	0.5 (0.7)
Outpatient bleeding risk, mean (SD)	1.2 (0.9)	1.1 (0.9)	1.3 (1.0)

Abbreviations: DVT, deep vein thrombosis; GED, General Educational Development; HMO, health maintenance organization; INR, international normalized ratio; mo, month; OTC, over-the-counter; PE, pulmonary embolism; PPO, preferred provider organization; SD, standard deviation; VTE, venous thromboembolism; wk, week.

[a]Only 131 participants completed the health literacy as measured using the 36-item Short Test of Functional Health Literacy in Adults.

[b]Other indications: atrial flutter, cerebrovascular accident, peripheral vascular disease, antiphospholipid syndrome, transient ischemic attack.

[c]Only 43 participants met criteria to determine the $CHAD_2DS_2$-VASc score.

[d]Only 89 participants met criteria to determine the Disability of the Arm, Shoulder, and Hand score.

had 6.2 (SD, 2.8) clinic visits with INR checks. Participants with suboptimal AC had a greater number of INR checks than patients with optimal AC (7.5 [SD, 3.0] vs 5.1 [SD, 2.1]; $P < .0001$). Less than half of participants (42.9%) had suboptimal AC. Mean TTR was significantly lower among participants with suboptimal AC compared with optimal AC (37.8% [SD, 15.7%] vs 80.1% [SD, 12.9%], respectively; $P < .0001$). Health literacy (adequate [71.4% vs 74.7%, suboptimal vs optimal AC, respectively] and inadequate/marginal [28.6% vs 25.3%, respectively]) was not significantly different by AC ($P = .69$). Greater proportion of individuals with trouble getting transportation to a clinic reported being disabled or unable to work (63.6%), had annual household income <$15 000 (45.5%), self-reported general health status as fair/poor (66.7%), and on average take 13.9 (SD, 5.2) prescriptions medications.

Commonly, participants either drove themselves (30.1%) or relied on someone else to drive them (21.1%) to a clinic. This was comparable between participants by AC (Table 2). Participants with suboptimal AC were significantly more likely to have indicated travel cost as a transportation barrier compared to those with optimal AC (28.1%% vs 13.2%, respectively; $P = .03$). While round-trip travel costs were not significantly different by AC, participants who reported transportation barriers due to travel costs (19.5%) had twice higher mean travel cost compared to those who did not ($12.00 [SD, $10.44] vs $6.04 [SD, $4.98], respectively; $P < .0001$). Self-reported travel time and geocoded travel distances were comparable across participants by AC.

Thirty-three (24.8%) participants reported having trouble getting transportation to ATC (Table 3). Mean TTR was significantly lower for participants who indicated transportation trouble compared to those who did not (53.8% [SD, 24.7%] vs 64.7% [SD, 25.0%], respectively; $P = .03$). The majority of participants (n = 87, 59.4%) reported at least one transportation barrier getting to a clinic. The most common

TABLE 2 Transportation outcomes by anticoagulation control

	Overall	Suboptimal AC	Optimal AC	
	n = 133	n = 57	n = 76	*P* value
Method of transportation, n (%)				
Drive—self	40 (30.1)	13 (22.8)	27 (35.5)	.39
Drive—someone else	28 (21.1)	14 (24.6)	14 (18.4)	
Ride share or taxi	4 (3.0)	1 (1.8)	3 (3.9)	
Walk	5 (3.8)	2 (3.5)	3 (3.9)	
Public transport (bus, train)	34 (25.6)	14 (24.6)	20 (26.3)	
Nonemergency medical transport	22 (16.5)	13 (22.8)	9 (11.8)	
Transportation trouble getting to clinic, n (%)	33 (24.8)	21 (36.8)	12 (15.8)	.01
Presence of ≥1 transportation barrier, n (%)	87 (65.4)	44 (77.2)	43 (56.6)	.01
Weather caused a missed clinic appointment	54 (40.6)	29 (50.9)	25 (32.9)	.04
Did not feel safe commuting to clinic	42 (31.6)	21 (36.8)	21 (27.6)	.26
Had physical challenges getting to clinic	36 (27.1)	16 (28.1)	20 (26.3)	.82
Transportation problems caused delayed scheduling, arriving late, or missing a clinic appointment	62 (46.6)	32 (56.1)	30 (39.5)	.06
Travel cost prevented getting to clinic	26 (19.5)	16 (28.1)	10 (13.2)	.03
Self-reported travel time, mean (SD)	40.1 (25.4)	41.0 (26.7)	39.4 (24.6)	.73
Geocoded travel distance, miles, mean (SD)	7.16 (7.1)	7.67 (6.7)	6.78 (7.4)	.48
Self-reported travel cost, $, mean (SD)[a]	7.16 (6.73)	6.81 (5.64)	7.41 (7.43)	.61

Abbreviations: AC, anticoagulation control; SD, standard deviation.
[a]Only 128 participants reported round-trip travel costs.

TABLE 3 Anticoagulation outcomes by transportation measures

	No trouble getting transportation to clinic	Trouble getting transportation to clinic		No transportation barriers to clinic appointment	Transportation barriers to clinic appointment	
	n = 100	n = 33	*P* value	n = 46	n = 87	*P* value
TTR, %						
Mean (SD)	64.7 (25.0)	53.8 (24.7)	.03	66.7 (22.3)	59.5 (26.5)	.12
Median (IQR)	67.7 (47.2-84.6)	53.5% (32.4-71.9)	.03	67.6% (56.7-82.2)	60.0 (41.2-82.9)	.14
AC control, n (%)						
Suboptimal (TTR<60%)	36 (36.0)	21 (63.6)	.01	13 (28.3)	44 (50.6)	.01
Optimal (TTR≥60%)	64 (64.0)	12 (36.4)		33 (71.7)	43 (49.4)	

Abbreviations: AC, anticoagulation control; IQR, interquartile range; SD, standard deviation; TTR, time in therapeutic range.

barriers were weather conditions preventing travel (40.6%) and lack of perceived safety while commuting (31.6%). Of the 100 participants who reported no trouble getting transportation to a clinic, over half (56.0%) indicated having at least one transportation barrier. Mean TTR was comparable in those reporting barriers compared to those without (59.5% [SD, 26.5%] vs 66.7% [SD, 22.3%]; *P* = .12).

Results of adjusted multivariable regression models are presented in Table 4. Participants reporting transportation trouble were 1.60 (95% CI, 1.07-2.39) times more likely to have suboptimal AC compared to those without trouble. Participants with at least one transportation barrier to clinic were 1.68 (95% CI, 1.01-2.80) times more likely to have suboptimal AC compared to participants without any transportation barriers to clinic.

In sensitivity analyses, no statistically significant trends or associations were observed between trouble getting transportation to a clinic (except for when TTR and INR in range was 65%) or having transportation barriers (except when TTR was 55%) and AC outcomes when the %TTR thresholds were varied (Figures S1 and S2).

TABLE 4 Multivariable log-binomial regression models of transportation trouble and barriers on suboptimal anticoagulation control

	Crude Model PR (95% CI)	Minimally Adjusted Model 1[a] aPR (95% CI)	Minimally Adjusted Model 2[b] aPR (95% CI)	Fully Adjusted Model[c] aPR (95% CI)
Trouble getting transportation to clinic appointment	1.77 (1.22-2.55)	1.66 (1.15-2.40)	1.65 (1.09-2.48)	1.60 (1.07-2.39)
Presence of transportation barriers to clinic appointment	1.79 (1.08-1.97)	1.71 (1.04-2.82)	1.83 (1.10-2.98)	1.68 (1.01-2.80)

Abbreviations: aPR, adjusted prevalence ratio; CI, confidence interval; PR, prevalence ratio.

[a]Adjusted for age, sex.

[b]Adjusted for annual household income.

[c]Adjusted for age, sex, annual household income.

4 | DISCUSSION

In an inner-city population of marginalized individuals on long-term warfarin management, those reporting trouble getting transportation to a clinic or reporting at least one transportation barrier were twice as likely to experience suboptimal AC over a 6-month observation period than those without. Over half of participants without transportation trouble reported at least one transportation barrier. This finding highlights an obvious, yet often overlooked point in the study of transportation in health care: barriers must be considered in conjunction with resources that enable the individual to overcome them. For example, cold weather may be a barrier; however, individuals with vehicle access who can ambulate freely may be able to overcome the weather challenges, whereas others may not. Furthermore, this suggests that perception of "trouble getting transportation to a clinic" and specific transportation barriers may reflect two separate aspects of transportation.

The most common barriers in our sample were weather and a lack of feeling safe in the commute to clinic. These barriers reflect characteristics of our urban sample, which was largely older women of color reporting fair/poor health status with limited economic means. Nonetheless, it is important that interventions to increase transportation access are appropriately targeted to the specific barriers within the population.

Geocoded distance and participants' reported travel time from their residence to a clinic were not predictive of AC. In the published literature, the impact of travel distance and travel time on patient health outcomes is mixed.[1,30] In a systematic review of 108 studies, 77% of studies identified associations between further distance from patients' homes to healthcare facilities with poor health outcomes (eg, survival, missed clinic attendance), 5% found a reversed association, and 18% found no associations.[30] Authors of this review noted the mixed evidence may be due to inconsistencies in methodologies and software used to calculate distances. Similar to some studies, our study used geodetic distance, which does not account for distance differences based on the mode of transportation, geographic area, or other transport-related factors. For instance, individuals in rural settings may have greater travel distance to their provider but with access to a vehicle, that distance may not be an issue. However, for an urban individual living within walking distance to their provider's clinic, the short distance may be difficult if they have physical disabilities or there is a lack of sidewalks to traverse. Some individuals with similar travel distances, for example, experience different travel times because of lack of access to a vehicle, use of public transit with multiple transfers, or extended wait times at transit stops, or experience physical challenges. These may explain why we did not observe an association between patient self-reported travel times and AC. Transportation barriers are multifaceted and interconnecting. Simply measuring travel distance and time may fail to capture other aspects of travel that impact clinic attendance.

While self-reported round-trip costs from a participant's residence to ATC was not associated with AC, travel cost was reported as a barrier significantly more often among participants with suboptimal AC. Medical-related transportation is considered a direct nonmedical cost that, while covered under Medicaid, is not reimbursed by all insurance plans. For individuals struggling financially, the out-of-pocket expense of transportation is a fundamental barrier and considered a social determinant of health.[2] In our study, individuals reporting cost as a barrier to ATC appointments paid over twice the amount for transportation to each visit than those who could manage the transportation costs. Considering that patients on warfarin require monthly to weekly clinic appointments, costs add up. In a separate study at a metropolitan anticoagulation clinic, transportation costs for a single clinic visit were estimated to be nearly \$11 per patient, which translated to between \$130 and \$560 annually depending on visit frequency.[31] For economically marginalized populations, the financial burden of transportation may simply be too high. This is not unique to warfarin. In a small study of HIV/AIDS patients, lack of money for transportation was a key factor for missed antiretroviral doses and missed medical appointments.[32] While some health plans include reimbursement policies for nonemergency medical transportation (NEMT), the financial burden to access such benefits and other restrictions can impact utility.[33]

In the context of health care, ride-share services (eg, Uber, Lyft) have been increasingly adopted as a strategy to address patients' transportation needs. Both Lyft and Uber have launched their respective health care service platforms (Lyft Concierge and Uber Health), and partnered with health care systems and payers such as Blue Cross Blue Shield and Humana, to provide patients transportation to their medical appointments.[34] Currently, 10 US state Medicaid programs have partnered with ride-share services to provide NEMT services to their members.[35] However, evidence demonstrating improved health outcomes by providing patients transportation via ride share or NEMT services is lacking.[17,36,37] While ride-share services may address some patients' needs, a more targeted menu of solutions is likely needed. For example, weather was the most common transportation barrier in this study. The degree to which offering a ride-share service would overcome weather is unknown. Additional research is warranted to understand the likely nuanced pathways through which transportation contributes to missed medical appointments and adverse health outcomes.

Patients on warfarin require reliable transportation to commute to their clinic appointments for warfarin monitoring and dose adjustments. Alternative strategies in the United States for patients on warfarin include switching patients from warfarin to direct oral anticoagulants (DOACs) and patient self-management or self-monitoring of INR.[38] DOACs (eg, rivaroxaban, apixaban, edoxaban, and dabigatran) are demonstrated to be as effective as warfarin for anticoagulation, have a broader therapeutic index, fewer drug and dietary interactions, and limited dose adjustments and do not require routine monitoring.[38] However, some patients (eg, renal dysfunction, extreme body weight) may not be ideal candidates for DOACs. The higher copays and restricted insurance plan coverage in some instances of DOACs can contribute to decreased medication adherence. Poor adherence to DOACs, similar to warfarin, results in suboptimal AC and higher risk of adverse events. Therefore, continued patient education provided by clinicians on the safe and effective use of DOACs is imperative to achieving optimal AC.

Evidence suggests patient self-management (ie, patient self-tests INR and self-adjusts medication dose) or self-monitoring of INR (ie, patient self-tests and reports to clinician results to receive dose adjustment instructions) are comparable to point-of-care testing at clinics for anticoagulation outcomes (eg, similar TTR, risk of thromboembolic events).[38,39] Patient self-management and self-monitoring require use of a portable INR device and testing strips. While Medicare and some commercial health insurance plans offer partial coverage for home INR devices, cost and burdensome prior authorization requirements may restrict patient access. Most studies conducted in the United States evaluated feasibility and efficacy of patient self-testing, and mainly focused on Caucasian populations and individuals with college or above education.[40] There is limited understanding of the feasibility and effectiveness of home INR testing among minority or low-income populations. Furthermore, not all patients have the capability or knowledge to appropriately operate the device and may require extensive education and training. While telemedicine services (eg, telephone or video calls) have progressively replaced in-person visits for acute and chronic condition management during the pandemic, not all patients have access to the technology to use these services. Shared decision making between clinicians and patients is necessitated to ensure that an optimized anticoagulation management strategy is selected, and barriers to achieving optimal AC, be it transportation, financial costs to medications, or access to home INR devices, are identified and addressed. For patients who select for in-person clinic visits, it is imperative to screen patients for transportation needs and offer patient-specific solutions.

Transportation and health outcomes have been dominated by research that focuses on distance and travel time between place of residence and health care provider/pharmacy.[1,17,30,41] As shown in Figure 1, the pathway linking transportation to poor outcomes may include a range of multilevel barriers (ie, access to public transit, transport-related costs, safety concerns) as well as feed through the direct provision of health care and/or through medication access in pharmacies. Medical appointments that result in the provision of medications, such as oncology treatments, or medication changes that directly impact clinical outcomes, such as insulin or warfarin dosing, may impact clinical outcomes. The model offers a guide for future research that can be modified in response to evidence-based inquiry.

Four systematic reviews of 204 studies have explored the impact of transportation on patients' health care access or health outcomes across a range of health conditions and populations.[1,17,30,41] To our knowledge, this is among the first to focus on AC. The current study is further notable in that transportation was measured using a validated transportation instrument designed specifically for urban populations.[18] Existing work in this area suffers from inconsistent operational definitions and weak measurement of transportation barriers.

Several limitations must be considered in interpreting the results of this study. First, this was a convenience sample that included patients who presented for their scheduled ATC appointments. The extent to which patients who missed an appointment did so because of transportation is unknown. The results may actually underestimate the risk of transportation on AC. Second, due to the nature of warfarin monitoring via INR checks, the scheduled frequency of ATC visits naturally varied among patients. Those with optimal INRs required less frequent ATC visits than those with INRs outside the therapeutic window, suggesting that the results may reflect associations and not causality. Specifically, while transportation problems may contribute to suboptimal control due to missed appointments, it is also true that suboptimal control may result in the need for more frequent visits, which may cause transportation problems. AC is multifactorial. Dietary changes, biochemical responses, and health status can impact patients' INR. Access to health care via transportation is only one pathway through which anticoagulation outcomes can be impacted. No conclusions can be drawn regarding the relationships between transportation and more serious cardiovascular outcomes (eg, major bleeds, hematologic events) as these were not measured. Finally, this study was conducted within a single urban academic health care system and among patients on long-term warfarin therapy. Results may not extend to other settings, to other disease states, or to populations with different demographic characteristics.

5 | CONCLUSION

Among a sample of inner-city, low-income individuals on chronic warfarin therapy, trouble getting transportation to a clinic and self-reported transportation barriers were nearly twice as likely to have suboptimal AC. The multifaceted nature of warfarin therapy necessitates frequent visits to clinic for management. Transportation barriers can disrupt anticoagulation monitoring and dose adjustments. This study offers some insights into potential screening questions that may identify patients at highest risk. It is imperative to recognize that transportation, while not a medical condition, is still an important component of adequate anticoagulation management for patients.

ACKNOWLEDGMENTS

We thank the Anticoagulation Center faculty and students for their significant contributions in patient recruitment and data collection (Nancy Shapiro, PharmD; Erika Hellenbart, PharmD, BCPS; James Lee, PharmD, BCACP; Meghan Mccomb, PharmD; Ellen Uppuluri, PharmD; Nina Huynh, PharmD, BCPS; Crissel Arban, PharmD; Jasmine Forrest, PharmD; Ravi Patel, PharmD; Sandra Walko, PharmD). We acknowledge the Research Open Access Publishing (ROAAP) Fund of the University of Illinois at Chicago for financial support towards the open access publishing fee for this article.

AUTHOR CONTRIBUTIONS

All authors contributed to the study design, acquisition and analysis and interpretation of the data, writing and reviewing of the manuscript, and decision to submit manuscript for publication.

RELATIONSHIP DISCLOSURE

CY, MN, NK, EN, and LS declare no conflicts of interest. AA is an employee of AbbVie, Inc. and may own stocks/shares in the company.

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SUPPORTING INFORMATION

Additional supporting information may be found in the online version of the article at the publisher's website.

How to cite this article: Yan CH, Naveed M, Alobaidi A, Kopfman M, Nutescu EA, Sharp LK. Association between transportation barriers and anticoagulation control among an inner-city, low-income population: A prospective observational cohort study. *Res Pract Thromb Haemost*. 2021;5:e12605. https://doi.org/10.1002/rth2.12605