Cumulative Incidence of Acute Kidney Injury in California's Agricultural Workers

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Objective: Chronic kidney disease in Central America suggests that agricultural work is potentially harmful to the kidneys. We investigated the cumulative incidence of acute kidney injury (AKI) over one work shift among agricultural workers in California. **Methods:** Serum creatinine was measured both before and after a work shift to estimate AKI. Associations of incident AKI with traditional and occupational risk factors were tested using Chi-square and trend tests and logistic regression. **Results:** In 295 agricultural workers, AKI after a summer work shift was detected in 35 participants (11.8%). Piece-rate work was associated with 4.52 adjusted odds of AKI (95% confidence interval 1.61 to 12.70). **Conclusion:** The cumulative incidence of AKI after a single day of summer agricultural work is alarming due to an increased risk of long-term kidney damage and mortality.

BACKGROUND

In areas of Central America, an epidemic of chronic kidney disease (CKD), termed Mesoamerican nephropathy (MeN), has been identified in the last two decades. MeN is estimated to be the cause of 20,000 deaths in Central America.[1] Although CKD typically affects men and women older than 60 years with a previous history of diabetes or hypertension,[2] MeN disproportionately affects young men typically in their 30s to 40s who work in agricultural jobs and lack a previous history of traditional risk factors, such as obesity, diabetes, or hypertension.[1,3] Men are affected more than women at a 3 or 4-to-1 ratio.[4] Research suggests that the etiology of the disease may be found in an occupational hazard of agricultural work.[3,5]

A risk factor for the development of CKD is the closely related condition, acute kidney injury (AKI).[6,7] AKI, formerly termed acute renal failure, is characterized by a rapid decrease in kidney function causing a rise in metabolic waste products, such as creatinine.[8] In 2012, the Kidney Disease Improving Global Outcomes (KDIGO) Working Group created a new working definition of the stages of AKI, based on elevations in serum creatinine and/or decreased urine output. In field studies, detection of CKD is difficult due to the need for consistent monitoring over a number of months; however, incident AKI can be detected on the basis of elevations in serum creatinine that occur rapidly and are detectable within hours.[9] Common risk factors for the development of AKI are the same as those for CKD, such as obesity, diabetes, and hypertension. Additional risk factors include dehydration from acute diarrhea, infectious diseases, venom from animal bites, and "natural" medicines.[10–13] The occupational and environmental hazards of agricultural work expose workers to conditions that may increase their risk for AKI.

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Few studies have examined the incidence of AKI among agricultural workers, despite the relationship between AKI and CKD and the apparently increasing prevalence of CKD among agricultural workers in Central America. Paula Santos et al[14] examined changes in serum creatinine after a day working in the sugarcane harvest in Brazil and found incident AKI in 18.5% of their sample. García-Trabanino et al[15] studied renal function among sugarcane cutters in El Salvador. They found that a high prevalence reduced renal function in pre-shift samples: 14% of men met the criteria for CKD based on decreased estimated glomerular filtration rate and 20% had elevated serum creatinine. After the work shift, they found that the prevalence of elevated serum creatinine had increased to 25% of their sample.[15]

California employs between 350,000 and 700,000 agricultural workers each year,[16] yet very little is known about their renal health. Studies of renal function and MeN suggest that AKI among agricultural workers could be an important but under-recognized problem and may be a precursor to further kidney damage. Despite occupational regulations on California's farms to protect the health of workers, many factors influence the ability of the worker to take advantage of these regulations. For example, variations in pay structure or in field tasks may put workers at an increased risk for AKI, as those paid by the piece may perceive that earnings are reduced when they take breaks. We conducted an exploratory study to investigate the cumulative incidence of AKI over a work shift in a sample of agricultural workers in California and to evaluate the association of both traditional and occupational risk factors with AKI in this population.

METHODS

Population

A convenience sample of 300 field workers was recruited from 15 farms throughout the prime agricultural region of the Central Valley of California during the summer of 2014 as part of the California Heat Illness Prevention Study (CHIPS). After receiving permission from the farm owner or the farm labor contractor, recruitment was conducted the day before data collection began. Bilingual, bicultural field staff explained the purpose and protocol of the study in Spanish to potential participants. If interested, participants were enrolled in the study after consent was obtained and field staff reviewed consent documents. Workers were included if they were 18 years of age or older, worked in the fields for at least 6 hours per day, and understood Spanish. They were excluded if they were pregnant, had experienced a recent illness or fever, or if they spent the majority of their work day in a tractor cab or other vehicle rather than working in the field. Each volunteer participated in the study for one work day only, and was given a small monetary incentive to compensate them for their participation in the study.

Due to time constraints at enrollment sessions and the dispersion of workers on the farms, we were unable to document exact rates of refusal. Overall, we estimate the refusal rate to be between 40 and 50%. Of those who agreed to participate, 295 of 300 had complete serum creatinine data and were included in the current analysis.

Data Collection

Pre-Shift Measures

A brief, pre-shift questionnaire was administered orally in Spanish to assess participant eligibility and to collect demographic information. A capillary blood sample was taken and analyzed using the handheld i-STAT point of care test (Abbot Point of Care, Inc., Princeton, NJ) to measure serum creatinine (traceable to isotope dilution mass spectrometry through the standard reference material SRM967).[17] Hemoglobin A1c (Hgb A1c) was measured using a Siemens DCA Vantage Analyzer (Siemens Healthcare Diagnostics Inc., Tarrytown, NY). Weight was measured in a base layer of clothing using a Seca 874 medical scale, and height was measured without shoes using a Seca model 213 stadiometer (Seca GMBH, Hamburg, Germany). All those involved in data collection were trained and supervised, and all equipment was regularly calibrated to ensure accuracy.

Post-Shift Measures

Following the work shift, approximately 7 to 12 hours later, a post-shift questionnaire was orally administered in Spanish to obtain information on health history and possible social and behavioral risk factors, including a personal or family history of kidney disease, work history, method by which they are paid, primary task on the farm, and general health rating. A second capillary blood sample was obtained to document serum creatinine, and a single blood pressure was obtained in the seated position using an automated blood pressure cuff (Omron blood pressure monitor, Lake Forest, IL).

Participants' body mass index (BMI), blood pressure, diabetes risk status, and blood creatinine level were shared with them at the conclusion of the day, and participants who had abnormal results were referred to local health clinics for follow-up care.

All study procedures were approved by the University of California, Davis Institutional Review Board.

Acute Kidney Injury

The primary outcome of interest was cumulative incident AKI during the work shift, defined by a specified increase in serum creatinine from the pre-shift to the post-shift measure. The KDIGO[18] definition and stages of injury were used to ascertain and classify changes in serum creatinine between the pre- and post-shift measures. AKI was defined as an increase of the post-shift serum creatinine by at least 0.3 mg/dL or at least 1.5 times the pre-shift creatinine. AKI staging was based on the following: stage 1 ($\geq$0.3 mg/dL or 1.5 to 1.9 times pre-shift serum creatinine); stage 2 (2.0 to 2.9 times pre-shift serum creatinine); and stage 3 ($\geq$3.0 times pre-shift serum creatinine).

Predictor Variables

Demographic variables thought to be associated with incident AKI were selected a priori on the basis of a review of the literature and feasibility of collecting data in the field. Demographic variables included sex (male vs female) and age (continuous). Occupational variables collected were years in agricultural work (continuous), type of farm task performed the majority of the day (picking, hoeing, irrigation, packing/sorting/planting, pruning/weeding, or other task such as machine maintenance or supervision of workers), and how the worker was paid (by the piece, hourly, or salary). Clinical data were also obtained. BMI was calculated from pre-shift height and weight measurements in a base layer of clothing (BMI = weight in kg/height in meters^2), and classified on the basis of WHO recommendations[19] as normal weight (BMI <25), overweight (BMI 25 to 30), or obese (BMI $\geq$30). Diabetes status was defined by standard categories of hemoglobin A1c (Hgb A1c)[20]: no diabetes (Hgb A1c <5.7%), pre-diabetes (Hgb A1c 5.7% to 6.4%), or diabetes (Hbg A1c $\geq$6.5%). Blood pressure was based on a single reading taken on the left arm and categorized as recommended by the Joint Commission[21]: normal blood pressure (<120/80 mm Hg and no self-reported anti-hypertensives), pre-hypertension (120 to 139/80 to 89 mm Hg), or hypertension ($\geq$140/90 mm Hg or taking anti-hypertensives). Estimated glomerular filtration rate (eGFR) was calculated using pre-shift serum creatinine based on the CKD-EPI equation[22] and categorized as $\geq$90 mL/min/1.73^2, 60 to 89 mL/min/1.73^2, or <60 mL/min/1.73^2. Self-reported information on personal or family history of kidney disease (yes vs no) and self-reported health status (excellent/good vs fair/poor) was also collected.

Statistical Analysis

Descriptive statistics were calculated for the outcome and potential risk factors stratified by sex. Subjects were classified on the basis of development of AKI and the unadjusted cumulative incidence of AKI was estimated with respect to candidate risk factors. Data were categorized, and unadjusted associations between incident AKI and candidate risk factors were tested for statistical significance using trend tests for ordinal variables[23] (via the Stata command nptrend) and Chi-square tests for nominal variables. Simple logistic regression was used to estimate the crude odds ratio (OR) of incident AKI for each of the worker characteristics. Variables for multiple logistic regression were chosen using a multi-step process. We first used a directed acyclic graph to encode investigator beliefs about the causal relationships among variables. We then screened variables for variation and dropped those without sufficient variation. In some cases, categories were collapsed to increase the number of observations in each cell and to improve the precision of the corresponding estimates. The resulting variables were included in a multiple logistic regression model to test adjusted associations for candidate risk factors. Data were analyzed both stratified by sex and pooled. Observations with intermittently missing values ($n = 6$) were dropped (ie, we performed a complete case analysis). All analyses were conducted using STATA12 (StataCorp LP, College Station, TX).

RESULTS

Characteristics of Sample

Most participants were male (64.7%), from Mexico (93.6%), with more than a decade of work in agriculture [mean 13.6 years, standard deviation (SD) 11.6] (Table 1). Most of the sample had normal eGFR at the morning sample (92.2%) and reported no history of kidney disease (75.6%). The sample tended to be overweight (42%) or obese (39.3%), without significant differences between the sexes. Male participants had significantly more pre-hypertension or hypertension than women (48.9% vs 38.5% and 38.4% vs 23.1%, respectively). Males were also more often employed in picking than females (31.1% vs 22.9%). The majority of participants were paid hourly (71.2%), which did not differ between males and females. Three persons had elevated serum creatinine at baseline (pre-shift), with values of 1.39, 1.3, and 1.2 mg/dL. These three men were aged 31, 69, and 39 years, respectively.

Post-Shift Data

Incident AKI occurred in 35 participants (11.8%), 13 females and 22 males (Table 2). Using the criterion of 1.5 to 1.9 times baseline, 17 participants were classified as stage 1 AKI. An additional 14 individuals met the criterion of an absolute increase of at least 0.3 mg/dL, yielding a total of 31 persons classified as stage 1 AKI [10.5%, 95% confidence interval (95% CI) 0.07 to 0.14]. There were four participants who had an elevation of 2 to 2.9 times baseline and were classified as stage 2 AKI (1.3%, 95% CI 0.01 to 0.03), and no one exhibited an elevation in serum creatinine

TABLE 1. Characteristics of Study Participants

	Total Sample ($n = 295$)		Male ($n = 190$)		Female ($n = 105$)		
	n	%	*n*	%	*n*	%	*P*
Age (mean, SD)	38.5	12.4	38.3	13.0	38.9	11.5	0.64
Country of origin							0.15
United States	16	5.4	13	6.8	3	2.9	
Mexico	276	93.6	174	91.5	102	97.1	
El Salvador	3	1.0	3	1.6	0	NA	
Level of education							<0.01
No education/do not know	9	3.0	8	4.2	1	0.9	
Less than high school	198	67.1	114	60.0	84	80.0	
Some high school	45	15.3	34	17.9	11	10.5	
Graduated high school	43	14.6	34	17.9	9	8.6	
Health status							<0.01
Excellent/Good	159	53.9	116	60.7	44	42.3	
Fair/Poor	136	46.1	75	39.3	60	57.7	
BMI[1]							0.26
Normal weight (<25 kg/m^2)	54	18.3	40	21.1	14	13.3	
Overweight (25–30 kg/m^2)	125	42.4	78	41.1	47	44.8	
Obese (>30 kg/m^2)	116	39.3	72	37.9	44	42.9	
HgbA1c*							0.67
HgbA1c <5.7% (No diabetes)	226	78.8	147	80.3	79	76.0	
HgbA1c 5.7–6.4% (Pre-diabetes)	40	13.9	24	13.1	16	15.4	
HgbA1c >6.5% (Diabetes)	21	7.3	12	6.6	9	8.7	
Blood pressure†							<0.01
Normal blood pressure (<120/80 mm Hg)	65	22.1	24	12.7	41	39.0	
Pre-hypertensive (120–139/80–89 mm Hg)	133	45.2	93	49.2	40	38.1	
Hypertension (>140/90 mm Hg)	96	32.7	72	38.1	24	22.9	
eGFR at morning sample‡							0.31
>90 mL/min/1.73 m^2	272	92.2	171	90.4	100	95.2	
60–89 mL/min/1.73 m^2	22	7.5	17	9.0	5	4.8	
<60 mL/min/1.73 m^2	1	0.3	1	0.5	0	NA	
History of kidney disease							0.53
None	223	75.6	146	76.8	77	73.3	
Personal history	14	4.7	10	5.2	4	3.8	
Family history	60	20.0	34	17.8	24	23.1	
Years in agricultural work (mean, SD)	13.6	11.7	14.8	12.6	11.3	9.5	<0.01
Pay method							0.15
Piece rate	77	26.1	56	29.5	21	20.0	
Hourly	210	71.2	128	67.4	82	78.1	
Salary	8	2.7	6	3.2	2	1.9	
Farm task							<0.01
Picking	83	28.1	59	31.1	24	22.9	
Hoeing	28	9.5	13	6.8	15	14.3	
Irrigation	35	11.9	35	18.4	0	NA	
Packing/Sorting/Planting	34	11.5	7	3.7	27	25.7	
Pruning/Weeding	59	20.0	24	12.6	35	33.3	
Other§	56	18.9	52	27.4	4	3.8	

Differences based on Chi-square tests between males and females.
BMI, body mass index (kg/m^2); HgbA1c, hemoglobin A1c.
*HgbA1c, from capillary blood sample.
†Blood pressure based on JNC7 categories.
‡Categorized based on KDIGO guidelines.
§"Other" includes supervising staff, machinery repair, shoveling dirt, or fumigati.

that classified him/her as stage 3 AKI. Differences in the incidence of AKI between male and female participants were not statistically significant based on Chi-square tests ($P = 0.83$).

For the group as a whole, mean pre-shift serum creatinine was 0.72 mg/dL (SD 0.18 mg/dL) and increased to the mean post-shift serum creatinine of 0.82 mg/dL (SD 0.21 mg/dL). Mean change in creatinine over the work shift was an increase of 0.09 mg/dL (SD 0.15 mg/dL), though creatinine values did not increase in all participants. Among those without AKI, mean pre-shift creatinine was 0.73 mg/dL (SD 0.17 mg/dL) and increased to a mean post-shift creatinine of 0.79 mg/dL (SD 0.19 mg/dL). Mean change in those without AKI was 0.06 mg/dL (SD 0.11 mg/dL). Among those classified as AKI, mean pre-shift creatinine was 0.65 mg/dL (SD 0.20 mg/dL) and increased to 1.01 mg/dL. Mean change in serum creatinine for those with AKI was +0.36 mg/dL (SD 0.13 mg/dL).

For simplicity, final unadjusted, bivariate analyses were run on models combining males and females (Table 3). On the basis of trend tests or Chi-square, the association between incident AKI and payment method was statistically significant ($P < 0.01$), with those being paid by the piece having higher proportions of AKI (24.7%). Unadjusted ORs were significant for weight classification and payment method. Obese participants had lower crude odds than

TABLE 2. Stages of Acute Kidney Injury Stratified by Sex

		Male ($n = 191$)			Female ($n = 104$)			Total ($n = 295$)			
KDIGO Stage	**Percentage Increase SeCr**	***n***	**%**	**(95% CI)**	***n***	**%**	**(95% CI)**	***n***	**%**	**(95% CI)**	***P****
											0.83
No injury	<1.5 times baseline	168	88.4	(0.84–0.93)	91	87.5	(0.81–0.94)	260	88.1	(0.84–0.92)	
Stage 1†	1.5–1.9 times baseline or >0.3 mg/dL increase	20	10.5	(0.06–0.15)	11	10.6	(0.05–0.17)	31	10.5	(0.07–0.14)	
Stage 2	2.0–2.9 times baseline	2	1.1	(−0.01 to 0.03)	2	1.9	(−0.01 to 0.05)	4	1.3	(0.01–0.03)	
Stage 3	3.0 times baseline	0	NA	NA	0	NA	NA	0	NA	NA	

CI, confidence interval; KDIGO, Kidney Disease Improving Global Outcomes; SeCr, serum creatinine measured via capillary sample before and after work shift.
*P value based on Chi-square tests of differences between males and females.
†Stage 1 classified based on meeting at least one of the criteria.

healthy weight participants in developing AKI (OR 0.38, 95% CI 0.25 to 0.95). Those paid by the piece had higher crude odds of developing AKI (OR 3.97, 95% CI 1.92 to 8.22) than those paid hourly. In models adjusting for all of the following: sex, age group, BMI, diabetes status, blood pressure, history of kidney disease, level of education, years in agricultural work, payment method, and farm task, the association between obesity and AKI was no longer significant [adjusted OR (AOR) 0.42, 95% CI 0.15 to 1.19] (Table 4.) However, the AOR (4.52, 95% CI 1.61 to 12.70) for payment method remained significant. No other associations were statistically significant in the final model.

DISCUSSION

In a study of 295 agricultural workers in the Central Valley of California, we found the cumulative incidence of AKI (stage 1 or stage 2) to be 11.8%, as defined by KDIGO classification based on elevations in serum creatinine over a single work shift. We also found that being paid by the piece was associated with four and a half times the odds of incident AKI in our sample. No other traditional risk factors, including age, BMI, diabetes, or hypertension, were associated with incident AKI.

We are aware of only two studies that have described AKI in a sample of agricultural workers, despite the potential link between kidney disease and agricultural work suggested by studies of MeN.[1,4,24] Our estimate of AKI cumulative incidence are somewhat lower than the study of sugarcane harvesters in Brazil, which detected incident AKI in five of 27 workers (18.5%) after a work-shift. Overall, the mean changes in serum creatinine in our sample were lower than estimates from Brazil. We found a mean change of 0.36 mg/dL in those with AKI, while Paula Santos et al[14] found a mean change of 0.48 mg/dL. In addition, in participants without AKI, we found a mean change of 0.06 mg/dL, while Paula Santos et al[14] found a mean change of 0.15 mg/dL. There are many reasons that these estimates may differ, including sampling variability, assessment method, underlying population health, work and ambient conditions, and differences in hydration. On the contrary, our results of a 10% increase in mean creatinine over the shift are similar to those of García-Trabanino et al[15] who also found a 10% increase in serum creatinine over a similar time period. Their results differ from ours, however, in their finding of elevated serum creatinine before the work shift in 20% of their sample. We found elevated creatinine in only 1% of our sample before the work shift, which makes the elevations in serum creatinine over a work shift in our study more pronounced. However, comparisons between our study and the above-mentioned studies are limited because those studies were performed among sugarcane cutters, and sugarcane harvesting is recognized as a particularly demanding crop with high levels of heat stress.[25–27] California agriculture (including fruits, olives, wine grapes, and melons) does not carry the same risks as harvesting sugarcane. Because of the limited number of studies of AKI in agricultural workers, further studies to obtain additional estimates are warranted.

Although years in agricultural work were not significantly associated with incident AKI in our sample, the increased odds of AKI among those being paid by the piece is a significant finding. Those who are paid by the piece may be more reluctant to take recommended breaks to rest in the shade or drink water because stopping work cuts into time that could be spent picking and may result in lower wages.[28] Therefore, those paid by the piece may inadvertently expose themselves to greater levels of occupational hazards, including heat illness and dehydration,[29] which may prove damaging to the kidneys. Fortunately, the method of paying agricultural workers is a modifiable risk factor and could be an approach to reducing incident AKI over a work-shift.

Not everyone in our sample who met criteria for AKI had serum creatinine levels above normal limits. In fact, only 18 of the 22 males (81%) had post-shift creatinine levels greater than 1.2 mg/dL, and two of the 13 females (15%) had post-shift creatinine levels greater than 1.1 mg/dL. KDIGO classification uses changes in serum creatinine to estimate AKI, which does not always imply that the second measure will be above normal limits. Changes in serum creatinine in themselves can be damaging to health. In fact, one study estimates a serum creatinine rise of 0.5 mg/dL increases the odds of mortality 6.5-fold among hospitalized patients.[30] Those in our sample with decreased kidney function at baseline (eGFR <89 mL/min/1.73 m^2) did not develop AKI over the course of a work-shift. Our results, then, suggest that baseline kidney function is not predictive of incident AKI.

The lack of association of AKI to other traditional risk factors, including age, obesity, diabetes, and hypertension strengthens the impression that the development of AKI in our sample may be related to occupational hazards rather than physiological disposition. Studies investigating the etiology of MeN have found significant associations between agricultural work and development of CKD. Our finding of the association of piece-rate work corroborates the association of kidney damage, albeit acute and transitory, to work circumstances, though further elucidation into the mechanisms of AKI in piece-rate workers is needed.

Injury to the kidneys after a single agricultural shift is disquieting, and there are several reasons that early detection of AKI is important in agricultural workers. First, after acute injury, serum creatinine often returns to normal limits, and the kidney injury may be unrecognized or remain subclinical.[8,31] This subclinical injury may precipitate further damage to the kidneys because elevations in serum creatinine are associated with an increased risk of long-term kidney damage and mortality.[30,32] Specifically, agricultural workers who develop AKI are at a risk for the development of CKD.[18,33,34] Second, agricultural workers in California are a vulnerable population, typically lacking insurance coverage and regular health care and may not have access to the care

TABLE 3. Proportion and Crude Odds Ratio of Incident AKI Among Common Risk Factors

	Total Sample	Participants With AKI			Odds of AKI		
	n = 295	n = 35			n = 295		
Sample Characteristic	n	n	%	P*	OR	95% CI	P
Sex				0.80			
Male	191	22	35.0		Reference	—	—
Female	104	13	37.1		1.10	(0.53–2.28)	0.81
Age (mean, SD)				0.46			
18–25 years	48	9	18.8		1.14	(0.37–3.58)	0.82
26–40 years	125	13	10.4		0.56	(0.20–1.60)	0.28
41–55 years	87	7	8.0		0.42	(0.13–1.36)	0.15
>55 years	35	6	17.1		Reference	—	—
BMI (kg/m^2)				0.052			
Normal weight (<25)	55	11	20.0		Reference	—	—
Overweight (25–30)	124	14	11.3		0.51	(0.21–1.21)	0.125
Obese (>30)	116	10	8.6		0.38	(0.25–0.95)	0.04
Diabetes status†				0.15			
No diabetes (HgbAlc <5.7%)	227	24	10.6		Reference	—	—
Pre-diabetes (HgbAlc 5.7–6.4%)	40	5	12.5		1.20	(0.43–3.34)	0.73
Diabetes (HgbAlc >6.5%)	20	5	25.0		2.80	(0.94–8.36)	0.06
Blood pressure (mm Hg)‡				0.37			
Normal blood pressure (<120/80)	65	11	17.2		Reference	—	—
Pre-hypertensive (120–139/80–89)	135	13	9.8		0.53	(0.22–1.26)	0.15
Hypertension (<140/90)	99	11	11.3		0.63	(0.25–1.55)	0.31
eGFR at morning sample§				0.07			
>90 mL/min/1.73 m^2	272	35	12.9		Reference	—	—
60–89 mL/min/1.73 m^2	22	0	N/A		N/A	N/A	N/A
<60 mL/min/1.73 m^2	1	0	N/A		N/A	N/A	N/A
History of kidney disease				0.55			
None	223	25	11.2		Reference	—	—
Personal history	14	2	14.3		1.32	(0.28–6.24)	0.73
Family history	60	8	13.8		1.27	(0.54–2.98)	0.59
Country of origin				0.75			
United States	16	2	12.5		1.05	(0.23–4.84)	0.95
Mexico	276	33	12.0		Reference	—	—
El Salvador	3	0	N/A		N/A	N/A	N/A
Level of education				0.99			
No education/do not know	9	1	11.1		0.91	(0.11–7.57)	0.93
Less than high school	198	24	11.8		Reference	—	—
Some high school	45	3	12.5		0.71	(0.23–2.15)	0.54
Years in agricultural work				0.64			
Five years or less	98	2	7.4		Reference	—	—
6–10 years	51	5	10.2		0.83	(0.30–2.32)	0.73
11–20 years	82	11	12.8		1.23	(0.50–3.00)	0.65
More than 20 years	64	8	12.7		1.06	(0.45–2.53)	0.89
Graduated high school	43	7	11.9		1.18	(0.45–3.08)	0.33
Payment method				<0.01			
Hourly	210	16	7.6		Reference	—	—
Piece rate	77	19	24.7		3.97	(1.92–8.22)	<0.01
Salary	8	0	N/A		N/A	N/A	N/A
Farm task				0.37			
Picking	83	14	16.. 9		Reference	—	—
Hoeing	28	3	10.7		0.59	(0.16–2.24)	0.44
Irrigation	35	2	5.7		0.30	(0.06–1.39)	0.12
Packing/Sorting/Planting	34	3	8.8		0.48	(0.13–1.78)	0.27
Pruning/Weeding	59	6	10.2		0.56	(0.20–1.55)	0.26
Other‖	56	7	12.5		0.70	(0.26–1.87)	0.48

BMI, body mass index (kg/m^2); HgbA1c, hemoglobin A1c.
*P value based on trend tests for ordinal variables or Chi-square tests for nominal variables.
†HgbA1c from capillary blood sample.
‡Blood pressure based on JNC7 categories.
§Categorized based on KDIGO guidelines.
‖"Other" includes supervising staff, machinery repair, shoveling dirt, or fumigation.

TABLE 4. Adjusted Odds of Incident AKI Among Select Risk Factors

	Odds of AKI[§]		
	n = 295		
Sample Characteristic	**AOR**	**(95% CI)**	***P****
Sex			
Male	Reference	—	—
Female	1.27	(0.53–3.08)	0.59
Age (mean, SD)			
18–25 years	1.28	(0.27–6.03)	0.31
26–40 years	0.64	(0.16–2.56)	0.53
41–55 years	0.50	(0.13–1.89)	0.31
>55 years	Reference	—	—
BMI (kg/m^2)			
Normal weight (<25)	Reference	—	—
Overweight (25–30)	0.63	(0.23–1.77)	0.39
Obese (>30)	0.52	(0.17–1.58)	0.25
Diabetes status[†]			
No diabetes (HgbA1c <5.7%)	Reference	—	—
Pre-diabetes (HgbA1c 5.7–6.4%)	2.15	(0.65–7.13)	0.21
Diabetes (HgbA1c >6.5%)	3.27	(0.83–12.81)	0.89
Blood pressure (mm Hg)[‡]			
Normal blood pressure (<120/80)	Reference	—	—
Pre-hypertensive (120–139/80–89)	0.67	(0.25–1.82)	0.43
Hypertension (<140/90)	0.78	(0.24–2.51)	0.68
History of kidney disease			
None	Reference	—	—
Personal or family history	1.73	(0.71–4.21)	0.23
Level of education			
Less than high school	1.18	(0.46–3.07)	0.35
High school or beyond	Reference	—	—
Years in agricultural work			
Ten years or less	Reference	—	—
More than 11 years	1.26	(0.54–2.95)	0.59
Payment method			
Hourly	Reference	—	—
Piece rate	4.52	(1.61–12.70)	<0.01
Farm task			
Picking	1.04	(0.37–2.91)	0.94
Other[||]	Reference	—	—

AKI, acute kidney injury; AOR, adjusted odds ratio; BMI, body mass index; HgbA1c, hemoglobin A1c.
*P value based on trend tests for ordinal variables or Chi-square tests for nominal variables.
[†]HgbA1c from capillary blood sample.
[‡]Blood pressure based on JNC7 categories.
[§]Categorized based on KDIGO guidelines.
[||]Other includes all other farm tasks except picking.

they need should the AKI not resolve and require further medical intervention. Although a majority of agricultural workers in California are undocumented immigrants from Mexico, California is one of the states that provide hemodialysis to undocumented immigrants with end-stage renal disease. In 2009, there were more than 61,000 hemodialysis patients in California, and costs of their treatment were estimated to be $51 million. Of these patients, 1350 were undocumented immigrants.[35]

Limitations

This study has multiple limitations that need to be recognized. First and importantly, the classification of AKI based on KDIGO ideally includes a measure of urine output over 6 to 24 hours in the staging of AKI. Because our data were collected in the field setting, documenting urine output was not feasible. Second, serum creatinine levels after a day of physical labor in agricultural fields must be interpreted with caution, as muscle injury causes release of creatinine, and it is possible that the physical exertion of field work results in muscle injury, which, in turn, results in elevated creatinine. Third, it would be ideal to follow participants over a longer period of time to detect consistent elevations of serum creatinine over a number of days of work or to assess other risk factors. However, longitudinal participation over many days or months would be difficult in this population. Fourth, the use of a convenience population may limit generalizability of the findings, but we believe this was not significant because we have no reason to suspect that participation was based on factors related to kidney health. Finally, although the current study was designed in response to recent research on MeN, our results do not provide evidence that there is a definitive link to cases of MeN. We were only able to include a limited number of variables related to occupational risks, which limits our contribution to the investigation of the etiology of MeN. MeN is an unexplained CKD, not AKI. Although there is a link between the two conditions, we did not assess CKD in our study. Our results do, however, point to a previously unrecognized and under-studied health outcome of agricultural work.

Strengths of the study include use of direct clinical measurements to estimate kidney injury in a difficult-to-study population. In addition, the comparison of pre- and post-work measurements allows us to estimate injury that occurs in a single day of work.

CONCLUSION

To our knowledge, this is the first study to examine the incidence of AKI in a population of agricultural workers in the United States. The cumulative incidence of AKI is alarming due to the recognized association between AKI and CKD, particularly in light of the growing prevalence of MeN in Central America and Mexico. The association between piece-rate work and incident AKI should be studied further, and may point to the need for modifications to methods of payment for agricultural workers to protect their health. Due to the vulnerability of this often undocumented population, early detection and prevention of AKI should be an important public health objective to prevent the potential development of CKD and the need for hemodialysis in this population.

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