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A pilot study examining the use of ultrasound to measure intravascular volume status in agricultural workers in a field-based research setting

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Abstract

Objective: The aim of this pilot study was to explore if internal jugular vein (IJV) ultrasound studies on agricultural workers in a field-based research setting could assess volume status during a hydration intervention.

Methods: Performed pre- and post-work shift IJV ultrasounds images on 30 agricultural workers. The IJV collapsibility index: < 39% (euvolemic) or ≥ 39% (hypovolemic).

Results: 13% (2/15) of the water group had an IJV collapsibility index ≥ 39%, and this increased to 19% (3/16) by the end of the work shifts. The electrolyte group did not have any workers start the work shift with an IJV collapsibility index ≥ 39%; however, at the post-shift assessment, 15% (2/13) were hypovolemic.

Conclusion: IJV ultrasounds may have the potential to be a useful tool to determine volume status in field-based research settings. Further investigation is needed to confirm these findings.

Keywords

ultrasound; volume depletion; environmental heat; agricultural workers

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Background

Heat waves, a phenomenon exacerbated by climate change, pose an emergent global health risk, and kidney disease is already recognized as a worldwide public health crisis (1). Agricultural workers are at higher risk than other occupational groups for heat-related fatalities,(2) heat-related illness (HRI),(3) and dehydration (4, 5). More recently, agricultural workers have also been shown to be at risk of acute kidney injury (AKI) and chronic kidney disease of unknown etiology (CKDu) that is associated with environmental heat exposure, dehydration, volume depletion, and intense physical activity (4-8). A meta-analysis on heat strain that included diverse populations, exposures, and occupations, found a 15% incidence of AKI or kidney diseases among those who worked in high ambient temperatures [Wet Bulb Globe Temperature (WBGT) >22°C (72°F) for very intense work; WBGT >25°C (77°F) for most occupations) for a minimum of 6 hours per day, 5 days per week, for 2 months of the year (9). Thus, risk arises from the work itself for agricultural workers who are at the center of two global public health challenges.

A combination of water (dehydration) and salt (volume) depletion due to laboring in hot and humid conditions has been hypothesized as a potential cause or mediator of AKI that may lead to CKDu among agricultural workers (4, 5, 10-12). A recent study with construction workers, in the hot desert climate of Saudi Arabia, found that exposure to this climate may also lead to kidney injury.(13) These studies have shown cross-shift changes in hydration biomarkers (urine specific gravity, serum sodium and potassium, and hematocrit), volume (blood pressure), and increases in kidney-related biomarkers (serum creatinine and blood urea nitrogen) (4, 5, 10-12). Field-based studies with agricultural workers have assessed volume depletion by comparing body weight taken at pre- and post-shift, with weight loss suggesting volume depletion (5, 11, 12). This method is non-invasive and feasible in the field; however, it is also imprecise and fails to account for factors such as bowel movements and food and fluid consumption that impact body weight (14). Furthermore, in a study with agricultural workers in Florida, weighing participants pre- and post-work shift was cumbersome due to layers of clothing and participant discomfort with disrobing for weight measurements (15).

Assessment of volume status is a major challenge in clinical medicine. Various non-invasive methods are used to obtain indirect information about intravascular volume including physical exam (vital signs, orthostatic changes in blood pressure/pulse) and clinical history (light-headedness, dizziness, more pronounced when standing). Decreased skin turgor, dry mouth, and thirst are used as indicators of dehydration (water loss). Most studies that assess volume depletion are in the hospital setting during acute illness in the emergency room or intensive care unit rather than in an occupational setting, and many of these studies also discuss how physical exams are not fully reliable in assessment of volume status (16-18). Ultrasound has emerged as a valuable non-invasive tool in measurement in volume status. There are many targets that can be evaluated using ultrasound including the internal jugular vein (IJV), inferior vena cava (IVC), and echocardiographic measures. The IJV has gained popularity as a target site given the ease of measurement and value in assessing fluid responsiveness.

The aim of this pilot study was to explore if internal jugular vein (IJV) ultrasound studies on agricultural workers in a non-clinical, field-based research setting can assess intravascular volume status.

Methods

After Institutional Review Board (IRB00112681) approval, in July 2021, the community health workers (CHW) from the Farmworker Association of Florida (FWAF) recruited a convenience sample of 30 agricultural workers in Central Florida. Workers were scheduled for a hydration intervention on a workday and assessed pre- and post-work shift. Each participant received a U.S. $70 gift card.

Detailed methods have been described previously (19). Briefly, workers were randomized to one of two hydration workday interventions: 5L (169oz) of plain water, or 5L of water with an electrolyte solution based on the World Health Organization (WHO) recommended oral rehydration formula (glucose 13.5 grams [g], trisodium citrate dihydrate 2.9g, sodium chloride 2.6g, potassium chloride 1.5g per one liter) (20). Systolic and diastolic blood pressure was measured using a digital system (Omron BP760N, Omron Healthcare Inc, Bannockburn, IL) pre- and post-shift after the worker had been seated for a minimum of five minutes. We collected urine and blood samples pre- and post-shift from the workers. A digital refractometer (Atago PAL-10S digital refractometer, Bellevue, Washington) was used to measure urine specific gravity (USG). USG values were categorized as follows: ≥ 1.020 (dehydrated) or < 1.020 (euhydrated). We used the point-of-care iSTAT Blood Analyzer with CHEM 8+ cartridges (Abbott Point of Care, Inc, East Windsor, NJ) to measure hematocrit, creatinine, and blood urea nitrogen (BUN) in finger-stick blood samples, from which we estimated glomerular filtration rate (eGFR) and calculated serum osmolality. eGFR was calculated with the Chronic Kidney Disease Epidemiology Collaboration (CKD-EPI) equation (21). Serum osmolality was calculated using the Martin-Calderon equation: 1.86(Na+K)+1.15(Glu/18)+(Urea/6)+14 (22). Inclusion criteria included being between 18 and 49 years of age and working in the agricultural sector for at least the last 4 weeks at the time of enrollment. Workers were excluded if they reported being pregnant, had type I or 2 diabetes mellitus, were under treatment for hypertension, or reported a history of glomerulonephritis, pyelonephritis, renal calculi, or a snake bite.

Ultrasound technique

Internal jugular vein (IJV) ultrasound studies were performed at the FWAF's office with a portable Butterfly IQ™ (Guilford, CT) pre- and post-shift to assess intravascular volume status. All measurements were performed by a single nurse researcher that was blinded to the allocation of randomization. The nurse researcher received training to perform the ultrasounds by a nephrologist who is trained and performs IJV ultrasounds to assess hydration status. Workers sat in a chair with their head at a 45° angle, and their head was rotated slightly < 30° to expose the right internal jugular vein (IJV). A small amount of water-based gel was placed on the probe. Pressure was applied to the probe once on the neck to locate the IJV and obtain ultrasound images, which were then digitally stored. The diameter of the IJV was measured during maximum and minimum distention during a respiratory cycle (Figure 1). IJV collapsibility index was calculated with the following equation: [(Max diameter - Min diameter)/(Max diameter)] X 100%. The IJV collapsibility index was categorized as follows: ≥ 39% (hypovolemic) or < 39% (euvolemic) (23). A nephrologist reviewed and interpretated the images and was blinded to the allocation of randomization.

Statistical analysis

Descriptive statistics were reported as mean and standard deviation, median and quartiles, and percent and sample size. No power analysis was completed since this was a pilot study. Analyses were performed using SAS® 9.4 software [SAS Institute Inc., Cary, NC, USA].

Results

A total of 30 agricultural workers were evaluated pre- and post-shift to assess intravascular volume status, except for one worker who missed the post-shift ultrasound. Therefore, 59 ultrasound studies were performed by the same nurse researcher. All participants agreed to have the ultrasound. The ultrasound process took five minutes to complete, and no adverse events occurred. Demographic and work characteristics are detailed elsewhere.(19)

In the water group, 13% (2/15) were hypovolemic before they started their work shift; this increased to 3 out of 16 (19%) after their work shift (Table 1). In comparison, the electrolyte group did not have any workers who started the work shift with hypovolemia, increasing to 2 (15%) post-shifts. Figure 2 shows changes in IJV collapsibility indices for each participant, with the electrolyte group predominantly increasing over the course of the day while the water group predominantly decreased. Pre-shift, fifty percent of the workers in the water group were dehydrated according to USG, falling to 6% post-shift. In the electrolyte group, 57% were dehydrated pre-shift and 50% post-shift. There were no significant changes in blood pressure or difference based on sex/gender.

Discussion

Using ultrasound to assess IJV collapsibility may have the potential to be a useful tool in determining volume status by researchers studying renal dysfunction, AKI, and CKDu in agricultural workers in the field.

This study evaluated patients in the morning and then the afternoon to assess if the workers were volume depleted after working a shift primarily in plant nurseries or ferneries during a hydration intervention pilot study. The results showed that three workers in the water group (6% of the total) and two workers in the electrolyte group (14% of the total) showed indications of volume depletion by the IJV collapsibility index post-shift compared to pre-shift. Of note, when evaluating USG, the workers in the water group had improvement in USG as compared to the electrolyte group. In the water group, IVJ values predominantly declined over the day, which is reflected in the reduction in dehydration as measured by USG. Similarly, in the electrolyte group, IVJ values generally increased over the day, and USG remained high. However, the water group did show a mild increase in serum creatinine; although not statistically significant. The increase in serum creatinine in the water group is interesting as it has been hypothesized that prolonged physical exertion in the heat and dehydration have been shown to increase indicators of kidney injury and dysfunction (4, 11, 12, 24, 25). Thus, further investigations are needed to study the relationship of hydration and prolonged physical exertion in the heat and additional factors that contribute to renal dysfunction along with hydration interventions.

Furthermore, the water group showed a decrease in dehydration in the afternoon but still showed an increase in volume depletion, presumably since these subjects only replaced their water losses and not their sodium losses. Since the electrolyte group received both salt and water replacement, the group had less volume depletion. Serum osmolality was relatively unchanged indicating that anti-diuretic hormone (ADH) was still under osmotic control – if the degree of volume depletion had exceeded 5%, then anti-diuretic hormone comes under non-osmotic release. Thus, the portable ultrasound measurements detected volume depletion and not just dehydration. Volume depletion is more important since it can reduce blood pressure when it is severe and poses a risk for AKI and potentially CKDu.

Our findings highlight the difference between dehydration and intravascular volume status, although these terms are sometimes used interchangeably. Dehydration refers to loss of water and does not always lead to volume depletion. Volume depletion is loss of salt and water that can potentially lead to lower blood pressure and renal perfusion. Most of the time, the kidney can compensate for volume depletion using other hormones such as ADH and activation of the renin-angiotensin-aldosterone system (RAAS) by increasing salt and water reabsorption. However, if volume depletion is severe enough, the compensatory mechanisms are unable to prevent volume depletion, and this could lead to acute kidney injury. This is important as repeated episodes of AKI can lead to chronic kidney disease, and this has been proposed to be a possible mechanism related to CKDu.

There are several limitations to this study. First, it is a small-sized pilot study that was performed at one location and thus findings are not statistically significant. Second, while IJV collapsibility index is a useful tool for assessing volume status, a single method has not been identified as the gold standard in volume status assessment, and a multifactorial approach is best taken. Furthermore, we used an IJV collapsibility index >39% to define volume depletion based on a small study involving patients in the intensive care unit, and it is unclear if this translates directly to our study population. Several strengths of this pilot study include the ability to compare the effects of drinking plain water to those of drinking an electrolyte solution, and the inclusion of multiple indicators of hydration in an occupational setting.

Conclusion

IJV ultrasounds in a field-based research settings may have the potential to be a useful tool to determine volume status for the study of renal dysfunction among agricultural workers. The IJV collapsibility index is an easy and reproducible measure that may be used in the field-based research settings to assess volume status. However, larger studies are needed to evaluate the accuracy of the IJV collapsibility index as an indicator of volume status among people outside the hospital setting.

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References

1. Vanholder R, Annemans L, Bello AK, et al. Fighting the unbearable lightness of neglecting kidney health: the decade of the kidney. Clinical kidney journal. 2021;14:1719–1730. [PubMed: 34221379]
2. Gubernot DM, Anderson GB, Hunting KL. Characterizing occupational heat-related mortality in the United States, 2000-2010: an analysis using the Census of Fatal Occupational Injuries database. American journal of industrial medicine. 2015;58:203–211. [PubMed: 25603942]
3. Mutic AD, Mix JM, Elon L, et al. Classification of Heat-Related Illness Symptoms Among Florida Farmworkers. Journal of nursing scholarship : an official publication of Sigma Theta Tau International Honor Society of Nursing. 2018;50:74–82. [PubMed: 29024370]
4. Mix J, Elon L, Thein Mac VV, et al. Hydration Status, Kidney Function, and Kidney Injury in Florida Agricultural Workers. J Occup Environ Med. 2018;60:e253–e260. [PubMed: 29271837]
5. Moyce S, Mitchell D, Armitage T, Tancredi D, Joseph J, Schenker M. Heat strain, volume depletion and kidney function in California agricultural workers. Occupational and environmental medicine. 2017;74:402–409. [PubMed: 28093502]
6. Krisher L, Butler-Dawson J, Yoder H, et al. Electrolyte Beverage Intake to Promote Hydration and Maintain Kidney Function in Guatemalan Sugarcane Workers Laboring in Hot Conditions. J Occup Environ Med. 2020;62:e696–e703. [PubMed: 33003044]
7. Laws RL, Brooks DR, Amador JJ, et al. Changes in kidney function among Nicaraguan sugarcane workers. International journal of occupational and environmental health. 2015;21:241–250. [PubMed: 25631575]
8. Campese VM. The unresolved epidemic of chronic kidney disease of uncertain origin (CKDu) around the world: A review and new insights. Clinical nephrology. 2021;95:65–80. [PubMed: 33300865]
9. Flouris AD, Dinas PC, Ioannou LG, et al. Workers' health and productivity under occupational heat strain: a systematic review and meta-analysis. Lancet Planet Health. 2018;2:e521–e531. [PubMed: 30526938]
10. Butler-Dawson J, Krisher L, Asensio C, et al. Risk Factors for Declines in Kidney Function in Sugarcane Workers in Guatemala. J Occup Environ Med. 2018;60:548–558. [PubMed: 29370016]
11. Moyce S, Armitage T, Mitchell D, Schenker M. Acute kidney injury and workload in a sample of California agricultural workers. American journal of industrial medicine. 2020;63:258–268. [PubMed: 31773783]
12. Garcia-Trabanino R, Jarquin E, Wesseling C, et al. Heat stress, dehydration, and kidney function in sugarcane cutters in El Salvador - A cross-shift study of workers at risk of Mesoamerican nephropathy. Environmental research. 2015;142:746–755. [PubMed: 26209462]
13. Al-Bouwarthan M, Quinn MM, Kriebel D, Wegman DH. Risk of Kidney Injury among Construction Workers Exposed to Heat Stress: A Longitudinal Study from Saudi Arabia. Int J Environ Res Public Health. 2020;17.
14. Kavouras SA. Assessing hydration status. Curr Opin Clin Nutr Metab Care. 2002;5:519–524. [PubMed: 12172475]
15. Thein Mac VV, Tovar-Aguilar JA, Flocks J, Economos E, Hertzberg VS, McCauley LA. Heat Exposure in Central Florida Fernery Workers: Results of a Feasibility Study. J Agromedicine. 2017;22:89–99. [PubMed: 28118110]
16. Teague S, Youssef GJ, Macdonald JA, et al. Retention strategies in longitudinal cohort studies: a systematic review and meta-analysis. BMC Med Res Methodol. 2018;18:151–151. [PubMed: 30477443]
17. Stéphan F, Flahault A, Dieudonné N, Hollande J, Paillard F, Bonnet F. Clinical evaluation of circulating blood volume in critically ill patients--contribution of a clinical scoring system. Br J Anaesth. 2001;86:754–762. [PubMed: 11573580]

18. Eisenberg PR, Jaffe AS, Schuster DP. Clinical evaluation compared to pulmonary artery catheterization in the hemodynamic assessment of critically ill patients. Crit Care Med. 1984;12:549–553. [PubMed: 6734221]
19. Chicas R, Suarez J, Elon L, et al. Hydration Interventions Among Agricultural Workers: A Pilot Study. Journal of Occupational and Environmental Medicine. 2022.
20. WHO. Who Drug Information. World Health Organization. 2002;16.
21. Levey AS, Atkins R, Coresh J, et al. Chronic kidney disease as a global public health problem: approaches and initiatives - a position statement from Kidney Disease Improving Global Outcomes. Kidney international. 2007;72:247–259. [PubMed: 17568785]
22. Martín-Calderón JL, Bustos F, Tuesta-Reina LR, Varona JM, Caballero L, Solano F. Choice of the best equation for plasma osmolality calculation: Comparison of fourteen formulae. Clinical Biochemistry. 2015;48:529–533. [PubMed: 25794428]
23. Killu K, Coba V, Huang Y, Andrezejewski T, Dulchavsky S. Internal jugular vein collapsibility index associated with hypovolemia in the intensive care unit patients. Critical Ultrasound Journal. 2010;2:13–17.
24. Bongers C, Alsady M, Nijenhuis T, et al. Impact of acute versus prolonged exercise and dehydration on kidney function and injury. Physiol Rep. 2018;6:e13734. [PubMed: 29890037]
25. Roncal-Jimenez C, Lanaspa MA, Jensen T, Sanchez-Lozada LG, Johnson RJ. Mechanisms by Which Dehydration May Lead to Chronic Kidney Disease. Annals of nutrition & metabolism. 2015;66 Suppl 3:10–13.

SMART Learning Outcomes

- Understand current practices and barriers of assessing volume depletion in field-based studies with agricultural workers.
- Gain insight on the potential use of ultrasound to assess internal jugular vein collapsibility to determine volume status by researchers studying renal dysfunction, AKI, and CKDu in agricultural workers in field-based research settings.

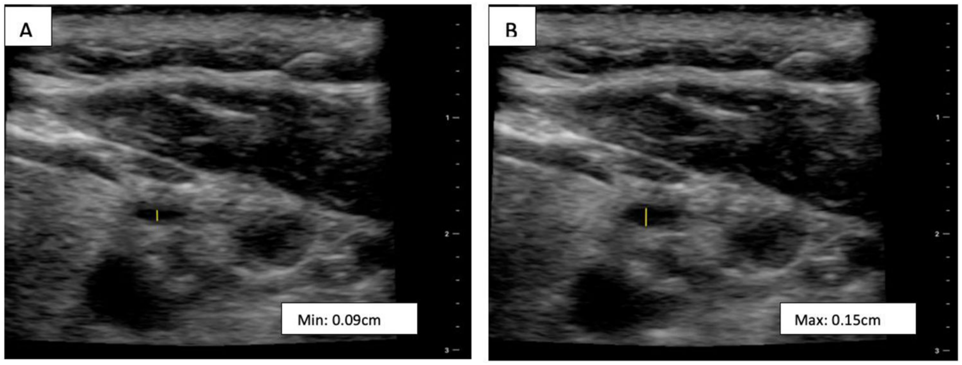

Figure 1. Ultrasound images of the internal jugular vein.

Figure A: IJV minimum AP diameter measurement during respiratory cycle.

Figure B: IJV maximum AP diameter measurement during respiratory cycle

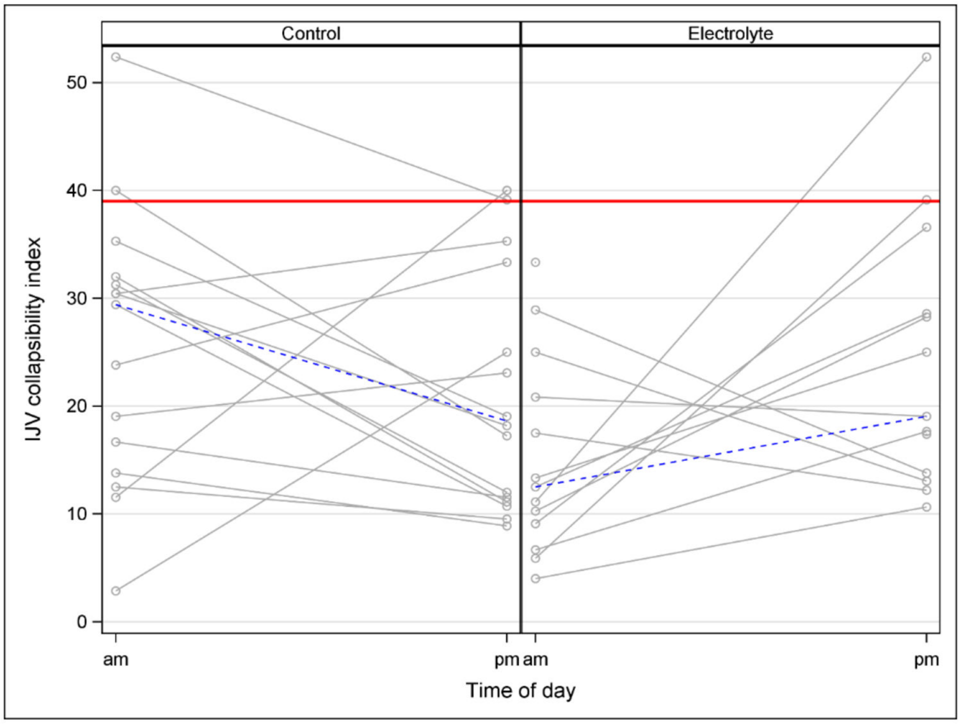

Figure 2.

Changes in IJV collapsibility index by type of beverage and time of day. The blue line connects median values, the red line is the hypovolemic limit, and grey lines connect individual's readings.

Table 1.

Cross-shift changes in hydration and renal biomarkers in 30 agricultural workers in Florida.

		Intervention			
		Water (n=16)		Electrolyte (n=14)	
	Time of Day	n	% or median (q1, q3)	n	% median (q1, q3)
Hypovolemia IJV collapsibility index ≥ 39%	**am**	2/15 *	13%	0/13 *	0%
	pm	3/16	19%	2/13	15%
Hypovolemia IJV collapsibility index, %	**am**	15	29 (14, 32)	13	13 (9, 21)
	pm	16	19 (11, 34)	13	19 (14, 29)
USG ≥ 1.020 (dehydrated)	**am**	8/16	50%	8/14	57%
	pm	1/16	6%	7/14	50%
Blood Pressure - Systolic	**am**	16	109 (100, 122)	14	121 (116, 129)
	pm	16	118 (108, 125)	11	117 (110, 129)
Blood Pressure - Diastolic	**am**	16	72 (69, 82)	14	76 (73, 82)
	pm	16	76 (70, 84)	11	77 (71, 82)
Serum Creatinine, mg/dL	**am**	16	0.6 (0.5, 0.7)	14	0.6 (0.4, 0.6)
	pm	13	0.7 (0.6, 1.0)	11	0.6 (0.4, 0.7)
Hematocrit	**am**	16	39.0 (36.8, 42.3)	14	39.0 (37.3, 42.5)
	pm	13	39.0 (36.0, 43.0)	11	39.0 (33.5, 40.5)
Serum Osmolality, mmol/kg	**am**	16	282 (279, 285)	14	283 (280, 284)
	pm	13	280 (278, 282)	11	283 (281, 285)
Blood Urea Nitrogen (BUN), mg/dL	**am**	16	12 (10, 15)	14	12 (9, 18)
	pm	13	13 (10, 14)	11	12 (9, 14)
Serum Sodium, mmol/L	**am**	16	141.0 (139.8, 143.0)	14	141.0 (140.0, 142.0)
	pm	13	140.0 (138.0, 142.0)	11	142.0 (142.0, 143.0)
Serum Potassium, mmol/L	**am**	16	4.2 (4.0, 4.3)	14	4.2 (4.0, 4.3)
	pm	13	4.0 (3.7, 4.2)	11	4.0 (3.9, 4.2)
Serum Glucose, mg/dL	**am**	16	110 (99, 130)	14	110 (102, 114)

		Intervention			
		Water (n=16)		Electrolyte (n=14)	
	Time of Day	n	% or median (q1, q3)	n	% median (q1, q3)
	pm	13	101 (97, 114)	11	102 (92, 126)

*2 morning readings early in the study were performed incorrectly and are not included (one in each group)