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Bioelectrical Impedance Analysis and Other Hydration Parameters as Risk Factors for Delirium in Rural Nursing Home Residents

Kennith R. Culp,[1] Bonnie Wakefield,[2] Mary J. Dyck,[4] Pamela Z. Cacchione,[3] Susan DeCrane,[1] and Sheila Decker[1]

[1]Adult & Gerontological Nursing, College of Nursing University of Iowa, Iowa City.
[2]VA Medical Center, Iowa City.
[3]Saint Louis University School of Nursing, St. Louis, Missouri.
[4]Mennonite College of Nursing at Illinois State University, Normal.

Background. The study investigators conducted a vigorous screening protocol for delirium in rural long-term care (LTC) facilities for a period of 28 days focusing on Bioelectrical Impedance Analysis (BIA) and other hydration parameters as risk factors.

Methods. A two-stage cluster sampling procedure was used to randomly select participants ($n = 313$) from 13 LTC facilities located in southeastern Iowa, stratified on facility bed size. BIA was used to estimate intracellular water (ICW), extracellular water (ECW), and total body water (TBW) on four occasions—baseline and follow-up days 7, 14, and 28. Volume estimates were calculated as a percent of body weight (%WT). Serum electrolytes and hematology were also measured. Delirium was measured with four strict criteria: a NEECHAM Confusion Scale score < 25, Vigilance ''A'' score > 2, a Mini-Mental Status Examination $<$ baseline, and a positive Confusion Assessment Method score.

Results. There were $n = 69$ delirium cases (22.0%). Blood urea nitrogen/creatinine ratios greater than 21:1 (odds ratio = 1.76, 95% confidence interval 1.02–3.06). No significant risk for delirium was associated with ICW, ECW, or TBW as a percent of body weight.

Conclusions. Some changes were observed with a slight decrease in ICW between day 7 and day 14 of follow-up that tended to follow an increase in delirium events, but in general the BIA measures did not predict delirium events.

DELIRIUM is a significant health care problem for older adults. Inadequate hydration has been linked to delirium in hospital-based studies (1,2), but these reports identify hydration problems after the onset of symptoms of delirium. Dehydration has been insufficiently identified as a prognostic indicator in elders. Warren and colleagues found that approximately 50% of elderly Medicare beneficiaries hospitalized with dehydration died within 1 year of admission (3). The literature is sparse on epidemiological investigations of delirium from long-term care (LTC) settings, usually based on using a secondary data analysis approach with the Minimum Data Sets (MDS). Estimates of delirium prevalence in LTC based on the MDS range from 14% to 23% (4,5). There are also no prior investigations of using Bioelectrical Impedance Analysis (BIA) as a predictor of delirium in nursing home residents.

Delirium is characterized by an acute onset of symptoms with a fluctuating course, an altered level of consciousness, and disturbances in orientation, memory, attention, thought, behavior, and the sleep–wake cycle, with specific physiologic factors underlying the problem (6,7). Hydration status and fluid intake have historically been problems among LTC elders (8,9), yet most investigations in LTC are limited to secondary data sources when measuring delirium (5,10,11) and not actual clinical observations. The primary purpose of this study was to conduct an intensive surveillance for delirium in older residents of rural LTC facilities in order to estimate the risk associated with changes in fluid compartment estimates derived from BIA measures and other hydration parameters of physiological significance. Since laboratory resources and geropsychiatric consultation for delirium are frequently lacking in rural communities, there is a need for a multicenter epidemiological study to assess risk factors for this disorder in these settings.

Methods

Design and Sample

This study used a longitudinal design. No diagnostic information about delirium symptoms was known to investigators at the start of follow-up; exposure was ascertained at baseline with the first BIA and set of serum measures. The basic design of the cohort is displayed in Figure 1. Data collection was conducted in two phases over a 28-day period for each participant. All cognitive testing and BIA measures were taken by trained registered nurse research assistants working for the investigators. Their training included over 80 hours in delirium symptom presentation and instrument use.

Phase I consisted of a 14-day intensive surveillance for delirium, with delirium screenings completed three times per day. Phase II surveillance consisted of one screening per day for an additional 14 days. Measures were taken at baseline and follow-up days 7, 14, and 28 for body weight

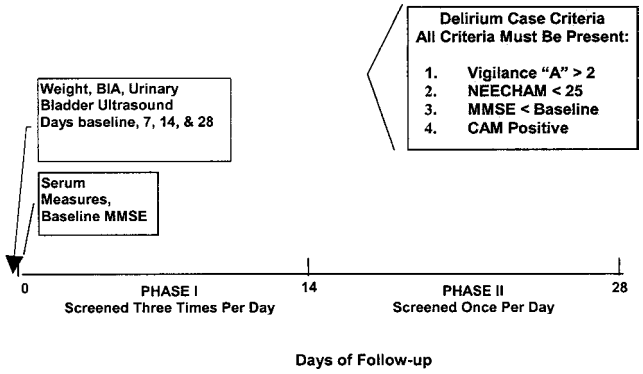

Figure 1. Delirium study design overview. BIA = Bioelectrical Impedance Analysis; MMSE = Mini-Mental State Examination; CAM = Confusion Assessment Method.

(WT), total body water (TBW), intracellular water (ICW), and extracellular water (ICW). Phase II surveillance (i.e., decreased delirium screening frequency) was implemented due to an increase in response burden evidenced by participant complaints from our earlier pilot work (12).

A two-stage cluster sampling approach was used in selecting the sample. The first stage was to randomly select 6 of 15 rural counties in southeast Iowa. Counties were included in the catchment area if they had a population under 40,000. A total sampling frame of 45 LTC facilities with operating capacity of 3554 beds served was obtained. The second stage was based on facility size; half of the participating facilities contained 75 beds or fewer and half had more than 75 beds. Thirteen facilities participated from the 6 counties, and participants were randomly selected based on these criteria:

1. Able to read, write, and speak English.
2. Aged 65 years or older.
3. No admitting diagnosis of a psychosis, head trauma, brain tumor, or toxin-related neurological disorder.
4. Admitted to a skilled or intermediate care bed for at least 30 days.
5. No implanted defibrillator.
6. No in-dwelling urinary catheter.

Participants with dementia were admitted to the study, provided they met all the criteria, but some persons with severe dementia were excluded by item 1 (above). Dementia status was determined by the primary care provider, and we abstracted the diagnosis from medical records. All protocols were reviewed by the University of Iowa Institutional Review Board (IRB), and consent was obtained from either the participant or his or her legal custodian as appropriate.

Delirium Screening

In order to confirm the accuracy of the delirium case assignment, each participant was coded as a delirium case if they met all of the following 4 previously described conditions: 1) NEECHAM (13) score less than 25; 2) a Mini-Mental Status Examination (MMSE) (12) at time of suspected delirium below the baseline MMSE score; 3) Vigilance ''A'' score (14) greater than 2; and 4) a Confusion Assessment Method (CAM) (15) positive rating. If these four criteria were met, the person was coded as a delirium screen positive.

Instruments

The NEECHAM Confusion Scale is a 9-item interpretive instrument designed for rapid and unobtrusive assessment that covers 13 of the possible 17 DSM-IV (*Diagnostic and Statistical Manual of Mental Disorders*, 4th edition) criteria for delirium. High internal consistency (0.90) and interrater reliability (0.96 to 0.99) have been established in both acute care and LTC (13,16). The NEECHAM total score ranges from 0–30; a score of 24 or less indicates possible delirium.

For measuring attention, the Vigilance ''A'' test was used; this consists of a series of 60 letters read to the participant, who indicates when the letter ''A'' is spoken by the research nurse. This test measures concentration and sustained attention; two or more errors are considered abnormal (14,17).

The CAM and MMSE are widely recognized instruments in the gerontology literature; a complete description of the reliability and validity of these instruments can be found elsewhere (12,18). The CAM (15), which consists of nine operationalized criteria for delirium derived from the DSM-III (19), is considered to be an effective screening tool for delirium (20).

Serum electrolyte levels were drawn at baseline and analyzed at a central laboratory. Serum chemistries were analyzed with the Cobas Integra 700 Clinical Chemistry Analyzer (Roches Diagnostics, Indianapolis, IN).

Urine specific gravity (SG) has a limited value in predicting hydration status due to the inability of elders to concentrate urine, but it was included in the data set so that it could be compared with other hydration indices. Urinary tract infection (UTI) was coded as present if the urine white blood cell (WBC) count was greater than or equal to 500 leukocytes μ/L.

A single-frequency Bioelectrical Impedance Analysis (BIA) instrument, the RJL Systems Quantum II (Clinton Township, MI) was used to measure total body water as a percent of body weight (TBW%WT), intracellular water as a percent of body weight (ICW%WT), and extracellular water as a percent of body weight (ECW%WT) (21,22). The technology is relatively simple and noninvasive, suitable for environments like rural nursing home facilities when serum electrolyte analyses in a medical laboratory are not immediately available. BIA measurements were taken at least 2 hours after meals and at least 6 hours after diuretic therapy doses. All participants were in a supine position with their arms and legs abducted at a 35° to 45° angle from the trunk of the body.

Results

There were 69 participants with delirium (22.0%) in the sample (n = 313), based on the previously described screening algorithm. A participant was considered a delirium ''case'' if he or she experienced a delirium event during the period of follow-up. The mean age for the total sample was 86.1 years (*SD* [standard deviation] = 7.17). Men represented 23.6% (n = 74) of the sample and women represented

Table 1. Baseline Serum Measures and Urinary Retention by Delirium Case Status

Variable	*N* (%) of Delirium Cases	*N* (%) of Noncases	Crude OR (95% CI)
BUN CR Ratio > 21:1*	30 (43.5%)	74 (30.3%)	1.76 (1.02–3.06)
Serum Na > 140 mEq/l	22 (31.9%)	69 (28.3%)	1.19 (0.67–2.12)
Urinary Bladder PVR > 100 ml	21 (30.4%)	71 (29.1%)	1.07 (0.56–1.91)

Notes: Delirium cases, $n = 69$; noncases, $n = 244$.

BUN = blood urea nitrogen; PVR = Postvoid residual; mEq/L = milliequivalents per liter; ml = milliliter; OR = odds ratio; CI = confidence interval; CR = creatinine; Na = sodium.

*$p = .05$.

76.4% ($n = 239$). Mean length of stay in the LTC facility was shorter for delirium cases (769.5 days, $SD = 665.7$) than noncases (856.2 days, $SD = 946.3$), but this was nonsignificant. There was no difference in likelihood of delirium between those aged 65–85 years ($n = 134$, 42.8%) and those older than 85 years ($n = 175$, 57.2%). Men were at slightly higher risk than women to develop delirium (OR [odds ratio] = 1.44, 95% CI [confidence interval] 0.79–2.62), but this was not significant.

Out of the 69 delirium cases, 27 individuals (24.3%) were diagnosed with dementia by the primary care provider (OR = 1.22, 95% CI 0.71–2.12). Delirium participants had a higher blood urea nitrogen/creatinine (BUN/CR) ratio (mean = 21.70, $SD = 7.22$) compared with nondelirium participants (19.81, $SD = 6.39$. $p = .036$). There were no differences in BIA or other indices for delirium cases with and without dementia.

Baseline cognitive factors differed by delirium status. Baseline MMSE scores were lower among delirium cases (mean = 18.3, $SD = 5.03$) compared with noncases (mean = 23.4, $SD = 5.44$) ($p < .001$). Baseline NEECHAM scores were significantly lower ($p < .001$) in delirium cases (mean = 24.8, $SD = 3.1$) compared with noncases (mean = 26.9, $SD = 2.3$).

Key hydration indices risk variables are displayed in Table 1. A BUN/CR ratio greater than 21 was significant for delirium ($p < .05$). Serum sodium levels were slightly higher in delirium cases (mean = 138.8 mEq, $SD = 4.0$) compared with noncases (mean = 138.6 mEq, $SD = 3.2$) but were not statistically significant. Serum chloride, potassium, and calcium levels were not significantly different between cases and noncases. Blood pressure, heart rate, and temperature were also not significantly different between those with delirium and those without. We did not find any significant differences between delirium cases and noncases for urine SG or postvoid residual urinary bladder ultrasound volumes.

Hematocrit was higher in delirium participants (mean = 38.2%, $SD = 4.5$) compared with those without delirium (mean = 38.0%, $SD = 4.6$). This may have represented hemoconcentration due to fluid loss.

Repeat Measures (Serum Electrolytes and BIA)

We entered all four BIA values and conducted a repeated measures analysis of covariance by delirium status. The main effect for delirium was not significant in all of the models, although the overall model was significant. For example, the Wilk's lambda value for ECW%WT was .966 with a calculated F value = 3.04, $df = 3$, $p = .029$. For ICW%WT, the Wilk's lambda value was .969 with a calculated F value = 2.78, $df = 3$, $p = .041$. For ICW%WT, the F value was 2.87 ($df = 3$, $p = .04$). Post hoc tests using orthogonal contrasts revealed lower ICW%WT on day 14 compared to day 7 (a drop from mean = 49.5%, $SD = 4.3$ to mean 48.8, $SD = 3.6$). This finding corresponded to the occurrence of 34 participants (49.3%) with delirium events between days 7 and 14. Summary comparisons of BIA measures and estimated ORs by gender are displayed in Table 2.

Table 2. Baseline BIA Hydration Measures by Gender and Delirium Case Status

	Case Status	Mean	*SD*	Crude OR (95% CI)
Female				
TBW%WT	Noncase	51.10	6.49	0.97 (0.92–1.02)
	delirium	49.78	6.13	
ICW%WT	Noncase	48.25	3.95	0.94 (0.87–1.03)
	delirium	47.41	3.83	
ECW%WT	Noncase	51.75	3.95	1.06 (0.97–1.15)
	delirium	52.59	3.83	
Resistance (ohms)	Noncase	543.94	109.09	0.99 (0.98–1.01)
	delirium	533.24	106.30	
Reactance (ohms)	Noncase	38.08	8.59	1.01 (0.96–1.04)
	delirium	38.20	8.16	
Male				
TBW%WT	Noncase	50.80	7.60	0.96 (0.90–1.03)
	delirium	48.79	6.52	
ICW%WT	Noncase	49.79	5.11	0.95 (0.85–1.07)
	delirium	48.81	3.91	
ECW%WT	Noncase	50.21	5.11	1.05 (0.93–1.18)
	delirium	51.20	3.92	
Resistance (ohms)	Noncase	563.78	119.47	0.99 (0.98–1.02)
	delirium	545.55	98.33	
Reactance (ohms)	Noncase	43.72	13.63	0.98 (0.94–1.03)
	delirium	41.30	7.74	

Notes: Female: Delirium cases $n = 49$; noncases, $n = 190$. Male: Delirium cases, $n = 20$; noncases, $n = 54$.

SD= standard deviation; OR = odds ratio; CI = confidence interval; TBW = total body water; WT = weight; ICW = intracellular water; ECW = extracellullar water.

Discussion

This study found a 22.0% period prevalence for delirium under vigorous clinical surveillance protocols across 13 LTC facilities in a rural catchment area. The four clinical criteria used for the recognition of delirium are as close to expert geropsychiatric consultation at the bedside as possible; however, we maintain that these are delirium screenings and not diagnostic assessments. Since there are no large-scale investigations of delirium prevalence in LTC based on clinical research methods, it is difficult to compare the estimate in this report with other findings. Mentes and colleagues (5) found a 13.98% prevalence in a secondary data analysis for LTC using the MDS. The variability between the work reported here and Mentes' work may be due to our protocol and under-reporting in the MDS used by Mentes.

Delirium participants did have higher BUN/CR ratios compared with those without delirium, but no other differences on any of the other hydration indices were

found. There was an attempt to identify dementia patients with superimposed delirium in these protocols, but we feel that severely demented patients do not screen well with the CAM and may have been excluded from the sample due to not being able to read or write English. This was purposeful, as a number of our screening tests require this ability and a special investigation of dementia and delirium is a topic for further investigation.

Instrumentation in delirium studies is an important consideration, and requiring positive scores on four tools to detect delirium may have been too strict in this study, thus deflating the true prevalence. Marcantonio and colleagues (23) used a CAM-only case method to detect delirium in a hospital study, but maintained that use of only one instrument for case detection may have limitations as well. Others rely on clinical interpretation or a previous version of the DSM. This variability in detection methods makes comparisons difficult across studies. Also, those investigations with a hospital sample where participants experience multiple physiological challenges cannot be expected to match our estimate from a generally healthy and stable LTC sample.

An increased BUN/CR ratio of greater than 21:1 was found to increase risk for delirium; however, there were no statistically significant findings for the body fluid compartments as estimated by the BIA measures nor was this validated with serum sodium levels. Some changes were observed with a slight decrease in ICW%WT between day 7 and day 14 of follow-up that tended to follow an increase in delirium events, but, in general, the BIA measures did not predict delirium.

ICW volume deficits have been known to increase the likelihood of confusional states in elders (24), but this may be due to hospitalized delirium cases having more acute changes in fluid volume levels. While the Mentes and colleagues (5) study demonstrated that inadequate fluid intake was a contributing factor to delirium in LTC settings, few other studies have investigated this link.

Changes in hematocrit might be used as an indicator of hydration status, but in reality these changes represent a fluctuation in plasma volume and not in TBW (25). Serum sodium concentration and plasma osmolarity have also been used to evaluate hydration status in elders, but these measures have proved to be unreliable in stimulating thirst in older adults (26). It is quite possible that altered hydration is either a contributor to or a result of the confusional state, or that there is not a hydration-related change in cognition at all, but rather the delirium event is caused by infection, hypoxemia, medication toxicity, or some other metabolic etiology (27).

Fluid balance disruption (i.e., altered ICW, ECW, and TBW levels) and delirium onset, as manifested by a change in body fluid compartment, was not supported by the BIA readings in this LTC sample. This may be due to the timing of the readings in our protocols. For example, waiting longer than 2 hours after a meal or distancing the BIA measurements longer than 6 hours from a diuretic dose administration time were possible sources of error. It is not possible to describe completely here, but every feasible attempt was made to obtain these measurements without disrupting care regimens in the host facilities. In any case, the systematic physiologic measures for estimating hydration are unparalleled when compared to intake and output records, which are notoriously inaccurate (28). A multifrequency BIA instrument also might have improved accuracy; however, given the complexity of our cognitive screening, we sided with the simpler technology for ease of use by our research assistants and for better acceptance by elderly participants.

There are several limitations in this study, most notably the lack of inclusion for severely demented patients and the difficulty in differentiating new delirium symptoms from preexisting delirium cases. There is a serious gap in instrument development for detecting delirium in persons with severe dementia, our protocol was not designed to be used with persons who were not able to read and write English, so dementia patients were underrepresented here. Indeed, what we interpreted as a new delirium event may represent a continuation of the first symptoms observed. Additionally, we may not have been justified using a ''rural'' sample here, although the premise that these LTC elders are further distanced from geropsychiatric care providers than urban elders does seem to be a worthy assumption. It has been suggested that rural nursing home residents have more health problems than do their urban cohorts (29), but there is no clear consensus. A direct comparison between urban and rural LTC elders using identical case-detection methods would be needed to resolve this issue.

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Address correspondence to Kennith Culp, PhD, RN, University of Iowa, College of Nursing, 358 Nursing Building, Iowa City, IA 52242. E-mail: ken-culp@uiowa.edu

References

1. Pompei P, Foreman M, Rudberg MA, Inouye SK, Braund V, Cassel CK. Delirium in hospitalized older persons: outcomes and predictors. *J Am Geriatr Soc*. 1994;42:809–815.
2. Cole MG, Primeau FJ. Prognosis of delirium in elderly hospital patients. *CMAJ*. 1993;149:41–46.
3. Warren JL, Bacon WE, Harris T, McBean AM, Foley DJ, Phillips C. The burden and outcomes associated with dehydration among US elderly, 1991. *Am J Publ Health*. 1994;84:1265–1269.
4. Marcantonio ER, Simon SE, Bergmann MA, Jones RN, Murphy KM, Morris JN. Delirium symptoms in post-acute care: prevalent, persistent, and associated with poor functional recovery. *J Am Geriatr Soc*. 2003; 51:4–9.
5. Mentes J, Culp K, Maas M, Rantz M. Acute confusion indicators: risk factors and prevalence using MDS data. *Res Nurs Health*. Apr 1999;22: 95–105.
6. Liptzin B, Levkoff SE. An empirical study of delirium subtypes. *Br J Psychiatry*. 1992;161:843–845.
7. Francis J. Delirium in older patients. *J Am Geriatr Soc*. 1992;40:829–838.
8. Chidester JC, Spangler AA. Fluid intake in the institutionalized elderly. *J Am Diet Assoc*. 1997;97:23–28; quiz 29–30.
9. Sheehy CM, Perry PA, Cromwell SL. Dehydration: biological considerations, age-related changes, and risk factors in older adults. *Biol Res Nurs*. 1999;1:30–37.
10. Langmore SE, Skarupski KA, Park PS, Fries BE. Predictors of aspiration pneumonia in nursing home residents. *Dysphagia*. 2002;17: 298–307.

11. Culp K, Mentes JC, McConnell ES. Studying acute confusion in long-term care: clinical investigation or secondary data analysis using the minimum data set? *J Gerontol Nurs*. 2001;27:41–48.
12. Culp K, Tripp-Reimer T, Wadle K, et al. Screening for acute confusion in elderly long-term care residents. *J Neurosci Nurs*. 1997;29:86–88,95–100.
13. Cacchione PZ. Four acute confusion assessment instruments: reliability and validity for use in long-term care facilities. *J Gerontol Nurs*. 2002; 28:12–19.
14. Pompei P, Foreman M, Cassel CK, Alessi C, Cox D. Detecting delirium among hospitalized older patients. *Arch Intern Med*. 1995;155: 301–307.
15. Inouye SK, van Dyck CH, Alessi CA, Balkin S, Siegal AP, Horwitz RI. Clarifying confusion: the confusion assessment method. A new method for detection of delirium. *Ann Intern Med*. 1990;113: 941–948.
16. Neelon VJ, Champagne MT, Carlson JR, Funk SG. The NEECHAM Confusion Scale: construction, validation, and clinical testing. *Nurs Res*. 1996;45:324–330.
17. Strub RL, Black FW. *The Mental Status Examination in Neurology*. 2nd Ed. Philadelphia: F A Davis; 1985.
18. Abraham IL, Manning CA, Snustad DG, Brashear HR, Newman MC, Wofford AB. Cognitive screening of nursing home residents: factor structures of the Mini-Mental State Examination. *J Am Geriatr Soc*. 1994;42:750–756.
19. American Psychiatric Association Work Group to Revise DSM-III. *Diagnostic and Statistical Manual of Mental Disorders: DSM-III-R*. 3rd Ed. Washington, DC: American Psychiatric Association; 1987.
20. Waszynski CM. Confusion assessment method (CAM). *Insight*. 2002; 27:43–44.
21. Meguid MM, Lukaski HC, Tripp MD, Rosenburg JM, Parker FB, Jr. Rapid bedside method to assess changes in postoperative fluid status with bioelectrical impedance analysis. *Surgery*. 1992;112:502–508.
22. Piccoli A. Identification of operational clues to dry weight prescription in hemodialysis using bioimpedance vector analysis. The Italian Hemodialysis-Bioelectrical Impedance Analysis (HD-BIA) Study Group. *Kidney Int*. 1998;53:1036–1043.
23. Marcantonio E, Ta T, Duthie E, Resnick NM. Delirium severity and psychomotor types: their relationship with outcomes after hip fracture repair. *J Am Geriatr Soc*. 2002;50:850–857.
24. Siegel AJ, Baldessarini RJ, Klepser MB, McDonald JC. Primary and drug-induced disorders of water homeostasis in psychiatric patients: principles of diagnosis and management. *Harv Rev Psychiatry*. 1998;6: 190–200.
25. Kavouras SA. Assessing hydration status. *Curr Opin Clin Nutr Metab Care*. 2002;5:519–524.
26. Kenney WL, Chiu P. Influence of age on thirst and fluid intake. *Med Sci Sports Exerc*. 2001;33:1524–1532.
27. McCusker J, Cole M, Dendukuri N, Belzile E, Primeau F. Delirium in older medical inpatients and subsequent cognitive and functional status: a prospective study. *CMAJ*. 2001;165:575–583.
28. Wise LC, Mersch J, Racioppi J, Crosier J, Thompson C. Evaluating the reliability and utility of cumulative intake and output. *J Nurs Care Qual*. 2000;14:37–42.
29. Duncan RP, Coward RT, Gilbert GH. Rural-urban comparisons of age and health at the time of nursing home admission. *J Rural Health*. 1997;13:118–125.

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