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Identification of the hydration state in emergency patients: correlation between caval index and BUN/creatinine ratio

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Abstract. – BACKGROUND: Dehydration is a frequent clinical problem. No single laboratory value has been found to be accurate; however, the BUN/Creatinine Ratio appears the most sensitive parameter. The respiratory variation (Caval Index, CIn) in the diameter of the inferior vena cava has been investigated as a non-invasive marker for the intravascular volume status.

AIM: The present study is performed with the aim to explore the relationship between CIn and BUN/creatinine ratio.

PATIENTS AND METHODS: This prospective, observational study was conducted at Emergency Department (ED) of San Paolo Hospital (Savona, Italy), in October 2011.

RESULTS: 113 patients were considered eligible (mean age of 63 years). We found a good correlation between CIn and BUN/Cr Ratio (Pearson Index 0.76, $p < 0.001$). Receiver operator characteristic curve (ROC) analyses indicated that the maximum value was 0.884 ($p < 0.0001$) and corresponded to CIn 60.7%, (sensitivity 79%, specificity 89%). CIn was a good predictor for patients with BUN/Cr ratio greater than 20, and was particularly strong in determining patients with lower BUN/Cr ratio.

DISCUSSION: Our study suggests that inferior vena cava could provide indications on the state of hydration of the patients: we found that a caval index greater than or equal to 60% was associated with a BUN/Cr Ratio over 20, which is considered an important marker for dehydration. Therefore, bedside sonography can give emergency physicians immediate information on patient volume status long before obtaining laboratory findings.

CONCLUSIONS: Our study seems to support the hypothesis that CIn can be a useful bedside marker to predict dehydration in Emergency Department (ED) patients.

Key Words:
Caval Index, Dehydration, BUN/Creatinine ratio, Emergency ultrasound.

Introduction

Dehydration is a clinical problem frequently observed in the Emergency Department. The first challenge for the emergency physician is to promptly recognize this condition, and then adopt adequate protocols of rehydration. Mistakes in these two evaluations could lead to increased morbidity and mortality. Undoubtedly dehydration is sometimes a difficult clinical diagnosis because of the lack of constant and specific signs. The first approach to dehydration consists of patient history and physical examination, including abnormal skin turgor, mucosal dryness, changes in blood pressure and respiratory rate. No single laboratory value has been found to be completely accurate in predicting the degree of dehydration or intravascular volume depletion[1,2]. However, the concentration of blood urea nitrogen (BUN) and the ratio of BUN to serum creatinine (BUN/Cr ratio) appear to be among the most sensitive parameters[1]. An invasive approach as the measurement of the central venous pressure is a useful method to evaluate the intravascular volume status and especially to monitor the intravenous fluid therapy[3]. Recently, the respiratory variation in the diameter of the inferior vena cava has been investigated as a non-invasive marker for the intravascular volume status in patients[4]. Moreover, the ultrasonographic measurement of the inspiratory collapsibility of the inferior vena cava (Caval Index, CIn) could be a useful non-invasive information which appears to correlate with the central venous pressure and can affect clinical decision-making[5]. Bedside, ultrasonographic evaluation of the inferior vena cava could be a non-invasive marker for low volume status for the emergency physician, thereby aiding the clinician in fluid management. If this is true, the determination of CI should correlate to laboratory values as BUN and BUN/serum creatinine ratio. The present study is performed with the aim to explore this relationship in patients observed for the first time in the Emergency room.

Patients and Methods

This prospective, observational study was conducted at Emergency Department (ED) of San Paolo Hospital (Savona, Italy), in October 2011.

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Selection of Participants

Inferior vena cava (IVC) sonography was performed by two experienced emergency physicians in any patients evaluated in two medical shifts for medical or traumatic causes, when the clinical picture indicated the need of blood tests.

During the data collection phase, physicians performing the measurements were blinded to blood sample results.

The procedure, non-invasive and always useful for diagnostic purposes, was explained to all patients with normal consciousness, and oral consent was obtained.

Patients were ineligible if an ultrasonographic measurement of the inferior vena cava could not be performed because of technical limitations, if the patients were intubated, in case of enlargement of right cardiac cavity (as in case of right cardiac failure, either acute or chronic) and in case of pregnancy.

Each physician performing the measurements for the study met the "Società Italiana di Medicina d'Emergenza-Urgenza (SIMEU)" standards for competency in emergency clinical ultrasound, and one was a certified instructor of SIMEU's echographic school for emergency ultrasound.

Methods of Measurements

While patients were supine, inspiratory inferior vena cava and expiratory inferior vena cava diameters were measured, 2 cm from the right atrial border in a long-axis/subxiphoid view with a 3.5 MHZ curvilinear probe (Esaote, MyLab 25, Genoa, Italy), using either a B or M Mode (with tracing perpendicular to IVC). Measurements were taken during a normal respiratory cycle, and the CIn was recorded (CIn is the difference between end-expiratory and end-inspiratory IVC diameter divided by the end-expiratory diameter) (Figure 1).

Data Analysis

Descriptive statistics were calculated for the study population's demographic, laboratory, and sonographic data. Patients were stratified by their Caval Indexes and comparative statistical analysis included *t*-Student test, and Pearson correlation analysis with test of significance were performed.

Test characteristics (sensitivity, specificity, VPV and VPN, likelihood ratios, 95% IC) were calculated.

Receiver operator characteristic curves were generated for cut-off values other than 60% to evaluate their ability to predict dehydration. The maximum values of the receiver operator characteristic curve were identified. $p < 0.05$ was considered statistically significant.

Results

During the observational period, 134 patients were evaluated, and 113 patients were considered eligible (60 female, 53 male, with a mean age of 63 years), with a mean CIn of 55.38% (SD 19.17) and mean BUN/Cr Ratio of 18.16 (SD 6.52) (Table I provides a description of our population). We found a good correlation between CIn and BUN/Cr Ratio (Pearson Index 0.76, $p < 0.001$, with significant *t*-Student test ($p < 0.01$, IC 99%).

Performance characteristics (sensitivity, specificity, predictive value, likelihood ratios) of the ability of Caval Index to predict BUN/Cr ratio more than 20 were calculated. Receiver operator characteristic curve analyses indicated that the maximum value for the receiver operator characteristic curve was 0.884 ($p < 0.0001$) and corresponded to CIn 60.7%, with a sensitivity of 79%

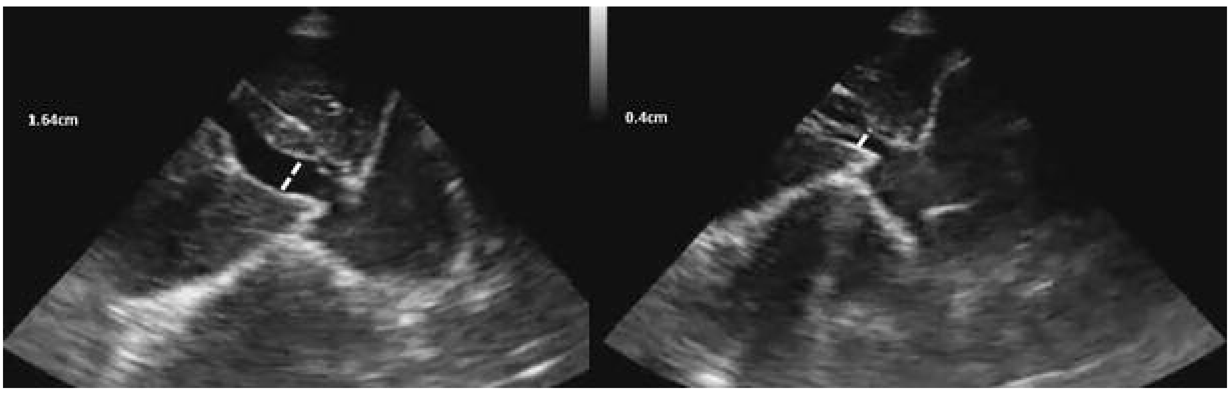

Figure 1. Inspiratory and expiratory inferior vena cava diameters were measured 2 cm from the right atrial border in a long-axis/subxiphoid view: in this case, the Caval Index was 75%.

(62.7-90.4 95% CI) and a specificity of 89% (80.1-95.3 95% CI), a LR+ of 7.40 (6.2-8.9 95% CI) and a LR- 0.24 (0.1-0.6 95% CI).

Caval index percentage was a good predictor for patients with BUN/Cr ratio greater than 20, and was particularly strong in determining patients with lower BUN/Cr ratio.

Discussion

Ultrasound has become an important tool for evaluating a variety of acute conditions in ED, because it is not invasive and relatively easy to perform with adequate training, portable and with good effectiveness. The close relationship between Caval Index and the central venous pressure has been proven by recent studies[5]. Although a complete agreement in international literature[6] has not been reached, the measurement of the central venous pressure[3] and the sonography of the inferior vena cava can be considered as markers useful in the evaluation of blood loss or intravascular volume depletion[7]. Since dehydration and changes in plasma osmolality significantly affect the CVP[8], it appeared logical to expect that the assessment of the inferior vena cava could provide indications on the state of hydration of the patients, correlating with one of its most important signs as the BUN/Cr ratio. Our study appears to support this statement because we found that a caval index greater than or equal to 60% was associated with a BUN/Cr ratio over 20, which is considered an important marker for dehydration[1]. Therefore, bedside sonography can give emergency physicians immediate information on patient volume status long before obtaining laboratory findings. Due to the overcrowding of the ED, it is not uncommon to wait over an hour for the results of blood tests, and so is important for us to have this measurement, because dehydration lacks univocal clinical signs, particularly in elderly patients and in those at their first evaluation in the ED. The evaluation of the caval index can be not only a useful support for diagnosis, but also for therapy, particularly in our time-dependent activity. In fact bedside CIn evaluation has the potential to reduce unuseful interventions as aggressive fluid infusion in patients with no need for such treatment. Generally these patients have a high negative predictive value of CIn less than 60, corresponding to a normal BUN/Cr ratio. CIn evaluation could allow a safer and aggressive procedure of fluid replacement in dehydrated or hypovolemic patients, sometimes avoiding invasive hemodynamic monitoring. Additionally, it is possible to assume that this method allows a more simple and immediate follow-up in many patients undergoing intensive hydration protocols.

Of course, emergency physicians must select their patients because the method cannot be applied indiscriminately to all of them. In details, some patients have technical limitations, mainly due to their body shape. Moreover, we have excluded patients with right cardiac overload documented by an ultrasound finding of enlargement of right chambers: in these cases the CIn correlates with CVP, but probably not with BUN/Cr ratio[9]. We have also excluded intubated patients because mechanical ventilation induces more marked changes in systemic venous return[10]. In spite of these limits, we can affirm that this ultrasound approach can give information in most patients.

Sonographic measurements were not repeated by a second physician on each patient, so there is a potential risk of operator-dependent errors. Moreover,

Table I. A brief description of our population.

Patients characteristic	Median (range)	95% CI	Standard deviation
Age, Y	62 (16-98)	–	–
Female (n = 60)	63 (20-98)	–	–
Male (n = 53)	61 (16-96)	–	–
Systolic Arterial Pressure (mmHg)	139.82 (60-230)	144.81-134.83	26.94
Diastolic Arterial Pressure (mmHg)	78.13 (30-110)	80.62-75.64	13.44
Median Arterial Pressure (mmHg)	98.66 (80-130)	101.70-95.69	16.19518
Heart Rate (pulses per minute)	90.11 (50-150)	93.71-86.50	19.46
Arterial Saturation (%)	96.96 (75-100)	97.71-96.20	4.08
Caval Index (95% CI)	54.95 (10.01-99.97)	49.68-58.60	19.17
Caval Diameter, expiratory, cm (95% CI)	1.44 (0.41-2.55)	1.30-1.54	0.46
Caval Diameter, inspiratory, cm (95% CI)	0.66 (1.8-0.001)	0.57-0.69	0.36
BUN/Creatinine Ratio (95% CI)	17.15 (5.01-41.70)	16.42-17.94	6.53

we know that dehydration and intravascular volume depletion are not synonymous, but in both conditions kidneys do not receive adequate blood supply and this should lead to a high BUN/Cr ratio. In addition, both conditions express a reduced preload and this latter can be demonstrated by means of CVC or a sonographic measurement of the inferior vena cava[11]. A high protein diet, steroids therapy, urinary tract problems, reduced renal flow due to severe heart failure are relatively common situations characterized by a high BUN/Cr ratio, but it is extremely unlikely that they can be associated to an increased CIn in absence of severe dehydration.

Conclusions

CIn can be a useful bedside marker to predict dehydration in ED patients. This is a safe and easy procedure, and a well-trained physician can perform it in less than five minutes

Conflict of Interest

None.

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