ORIGINAL ARTICLE

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What water should I drink, Doc?

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ABSTRACT

Chronic kidney disease (CKD) is commonly associated with normal anion gap metabolic acidosis and its correction has shown multiple benefits, such as improved bone health and nutritional status, a slower progression of CKD and a lower incidence of end-stage renal disease. *Kidney Diseases Improving Global Outcomes* 2013 recommend maintaining serum bicarbonate concentration in the normal range (≥ 22mEq/L), which is usually accomplished by using a starting dose of 0.5 – 1mEq/kg/day of bicarbonate supplements. Nutritional strategies incorporating base-producing fruits and vegetables might show equal value. In this context, we analyzed the ingredients instead of labels of widely sold bottled water in Portugal to identify the most bicarbonate-rich bottled water which might help mitigate the complications of CKD chronic metabolic acidosis. We included 32 varieties of bottled water sold in Portuguese supermarkets. If a 70kg-adult is advised to ingest a bicarbonate dose of 0.5 – 1 mEq/kg/day, this amount could be supplied by 1 – 2 liters of *Frize*® per day, approximately the same as in *Pedras Salgadas*® and *Vidago*® (1.1 – 2.2 liters). We concluded that, along with nutritional strategies addressing dietary H+ reduction, Portuguese CKD patients with chronic metabolic acidosis could benefit from drinking water brands such as *Frize*®, *Pedras Salgadas*® or *Vidago*®.

Keywords: chronic kidney disease, metabolic acidosis, water

INTRODUCTION

Chronic kidney disease (CKD) is commonly associated with normal anion gap metabolic acidosis. As the glomerular filtration rate (GFR) falls below 30 mL/min, up to one third of patients have some degree of hypobicarbonatemia, usually between 12-20 mEq/L[1]. This results from impaired hydrogen (H^+) elimination by the kidney, mainly due to a reduced total ammonium excretion. High anion gap metabolic acidosis may occur later, at GFR below 15 mL/min, due to retention of unmeasured anions such as sulphate, phosphate, urate and hippurate[2].

CKD patients with metabolic acidosis exhibit increased muscle wasting, bone demineralization and accelerated decline of GFR. They are also more likely to reach end-stage renal disease and appear to have a higher mortality than CKD patients without metabolic acidosis[3-6]. Even before overt acidosis settles, at a stage of eubicarbonatemic and subclinical metabolic acidosis (HCO_3^- ≥ 22mEq/L), the kidney develops compensatory mechanisms, such as increased ammonium excretion per nephron. This may cause further injury in CKD, probably due to ammonia-induced complement activation and increased production of profibrotic and proinflammatory molecules[7,8].

Conversely, evidence suggests that correction of metabolic acidosis in CKD patients can lead to improved bone health and nutritional status, slower CKD progression and a lower incidence of end-stage renal disease[9-14]. *Kidney Diseases Improving Global Outcomes* (KDIGO) 2013 recommend maintaining serum bicarbonate concentration in the normal range (≥ 22mEq/L), which is usually accomplished by using a starting dose of 0.5 – 1mEq/kg/day of bicarbonate supplements when below this threshold (HCO_3^- < 22mEq/L)[15]. Furthermore, some patients with CKD could benefit from alkali even before overt acidosis develops (HCO_3^- ≥ 22mEq/L), although this subset of individuals is not yet well defined[7,12,16,17].

Nutritional strategies designed to reduce H+ intake, such as eating base-producing fruits and vegetables and reducing animal-based protein intake, might show equal value[16,18,19]. In this context, we analyzed the ingredients of bottled water widely sold in Portugal to identify the most bicarbonate-rich bottled water which might help mitigate the complications of CKD chronic metabolic acidosis. French nephrologists frequently recommend *Vichy*® water, the bicarbonate concentration of which is approximately 3g/L. When faced with the question of which water to choose, the nephrologist should be able to provide an informed answer to the patient.

SUBJECTS AND METHODS

We included bottled water sold in Portuguese supermarkets. Those whose labels did not mention its bicarbonate concentration were excluded. Descriptive statistics were carried out using frequencies/percentages, means and standard deviations, or medians and interquartile ranges according to each variable's distribution. To determine the volume of water one needs to drink to administer 0.5 or 1mEq of bicarbonate/kg/day, we used the formula: (weight x 30.5 or 61)/water HCO_3^- concentration (mg/L).

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RESULTS

Thirty-two bottled waters were included in the study, of which 11 were sparkling water (Table I). Median bicarbonate concentration was 155 mg/L (IQR 354,3); maximum bicarbonate concentration 2100 mg/L (*Frize*®) and minimum bicarbonate concentration 2.6 mg/L (*Caldas de Penacova*®) (Table I and Figure 1). If a 70kg-adult was advised to ingest a bicarbonate dose of 0.5 – 1 mEq/kg/day, this amount could be supplied by 1 – 2 liters of *Frize*® per day, approximately the same as in *Pedras Salgadas*® and *Vidago*® (Table II).

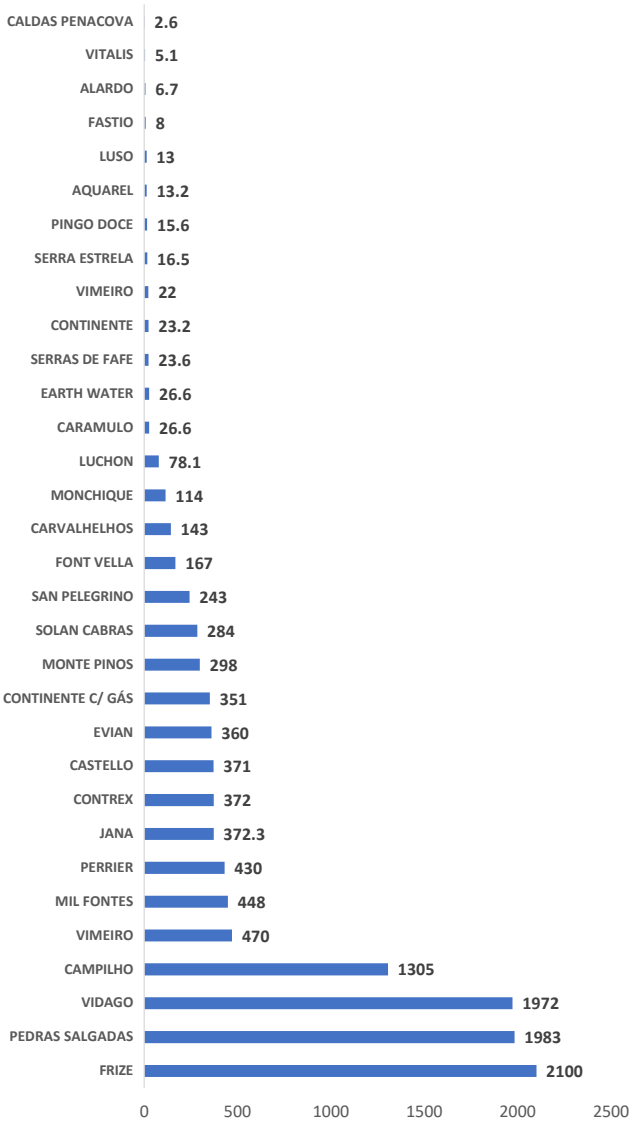
Table I

Descriptive statistics

Sample	n = 32
Sparkling water	11 (31%)
Median [HCO_3^-]	155 mg/L (IQR 354,3)
Maximum [HCO_3^-]	2100 mg/L (Frize®)
Minimum [HCO_3^-]	2.6 mg/L (Caldas de Penacova®)
Median [Na^+]	8.7 mg/L (IQR 52,8)
Median [Cl^-]	9.1 mg/L (IQR 25,3)
Median [Ca^{2+}]	36 mg/L (IQR 99,3)

Figure 1

Water HCO_3^- concentration in mg/L



DISCUSSION

Of the bottled water available in the Portuguese market, 1 to 2 liters per day of brands such as *Frize*®, *Pedras Salgadas*® or *Vidago*® could deliver the average man (70kg) the same amount of bicarbonate as 3 to 6 pills of 1g $NaHCO_3$, respectively (Table II). As shown by Goraya *et al.*, dietary strategies such as eating more base-producing fruits and vegetables were non inferior to oral $NaHCO_3$. These effectively increased serum bicarbonate concentration, reduced urinary markers of kidney injury and slowed the rate of disease progression, even for metabolic acidosis that is less severe than that for which KDOQI recommends therapy (HCO_3^- ≥ 22mEq/L)[16,17,19]. Such dietary strategies were designed to reduce the potential renal acid load by 50% and included apples, apricots, oranges, peaches, pears, raisins, strawberries, carrots, cauliflower, eggplant, lettuce, potatoes, spinach, tomatoes, and zucchini. This diet carried additional benefits such as a

Table II

Volume of water to provide 0.5 – 1 mEq HCO_3^-/kg/day (70kg adult)

Bicarbonate pill	(-)	HCO_3^- mg	Na^+ mg	Cl^- mg	NaCl mg	Ca^{2+} mg	Doses 0.5 mEq/day	Doses 1 mEq/day
$NaHCO_3$- 1g tid	(-)	2250	750	0	0	0	1	2

Water	pH	HCO_3^- mg/L	Na^+ mg/L	Cl^- mg/L	NaCl mg/L	% NaCl MDD/L	Ca^{2+} mg/L	Volume 0,5 mEq/day (L)	Volume 1 mEq/day (L)
Frize®	(-)	2100	635	122	201	5%	106	1.0	2.0
Pedras Salgadas®	6.1	1983	577	30	50	1,3%	102	1.1	2.2
Vidago®	6.2	1972	621	31	51	1,3%	83	1.1	2.2

tid, *ter in dae* (three times a day); HCO_3^-, bicarbonate; Na^+, sodium; Cl^-, chloride; NaCl, sodium chloride; Ca^{2+}, calcium; mEq, miliequivalents$^-$; MDD, maximal daily dose (considering 4g as maximal advised NaCl daily intake)

decrease in body mass index and systolic blood pressure[16]. However, in advanced stages of CKD, patients are at risk of hyperkalemia and are advised to restrict many fruits and vegetables which are also rich in potassium. Water, as a potassium-free element, can be more simply recommended to those at risk of hyperkalemia to help reduce the renal acid load.

Concerns raised by mineral water are its other mineral content, such as sodium, chloride and calcium, as well as their fluid volume (Table II). Given the potential of sodium-related fluid retention, an important consideration is whether the sodium content is safe in CKD. On one hand, these waters have a lower sodium content *per* liter than 3g of the oral $NaHCO_3^-$ pill (Table II). Sodium bicarbonate was not associated with an increase in systolic blood pressure compared to standard care[9]. On the other hand, these waters also have chloride, which is absent in $NaHCO_3$ pills. Evidence suggests that fluid retention and increased blood pressure is more likely to occur when sodium is accompanied by the chloride anion[20]. This is possibly because of hyperchloremia-induced tubuloglomerular feedback, renal vasoconstriction and reduced GFR[21-23]. However, sodium chloride concentration is low, especially in *Pedras Salgadas*® and *Vidago*®, representing approximately 1 to 5% of the maximal advised daily dose[24] (Table II), the same as one glass of milk.

Concerning fluid volume, patients with CKD generally have isosthenuria and their advised volume intake is up to 1.5 liters per day in order to avoid hyponatremia, with adjustments for hot climate and insensible fluid loss[24]. This is within the necessary volume to administer a fair amount of bicarbonate, although patients with concurrent hyponatremia-predisposing conditions, such as heart or hepatic failure, might not be able to achieve it. Furthermore, in most CKD patients, this could mean drinking exclusively bicarbonate-rich water and we think that people should not drink much more than their thirst requires. Instead, our recommendation should be interpreted within a broader dietary strategy, combining a reduction of acid-producing and favoring base-producing foods and beverages. We also intend to provide an informed suggestion to those who buy bottled water and want to get the best out of it by choosing one that supplements their bicarbonate need.

Concerning calcium, in patients with moderate-to-advanced CKD, the recommended elemental calcium intake is 800 to 1000mg per day[24], making the low calcium content in bottled water safe (Table II). In terms of lithogenicity, the influence of different types of water is probably negligible, since the main endpoint is to increase urinary volume[25].

Finally, when recommending a specific brand of water, one should look for the bicarbonate concentration, instead of the pH, as the latter refers to the negative logarithm of the H^+ concentration and the former to the acid-neutralizing capacity of the water (alkalinity), reflecting its ability to attenuate changes in pH. The pH of the water is a measure of the acid–base equilibrium and, in most mineral waters, is controlled by the carbon dioxide-bicarbonate-carbonate system. An increase in carbon dioxide concentration will therefore lower the pH, whereas a decrease will cause it to rise. *Frize*®, *Pedras Salgadas*® or *Vidago*® are sparkling acidic water because of their high CO^2 content, which is quickly eliminated by the lungs. Nonetheless, they have a high bicarbonate concentration.

One limitation of our study is the fact that tap water was not compared to bottled water. We know that 99% of Portuguese tap water is safe, cheap and environmentally friendly, according to the 2018 Annual Report on Water and Waste Services in Portugal. However, we are not aware of its bicarbonate concentration and it probably varies throughout the country. Another limitation of our study is its non-experimental nature. The capacity of bicarbonate-rich water to raise bicarbonate serum levels was not tested. We found no studies addressing this hypothesis and this will be our next goal. However, one common alkalinizing agent is sodium bicarbonate powder (baking soda) dissolved in water[26], which we believe to be comparable to bicarbonate-rich water.

In conclusion, along with nutritional strategies addressing dietary H+ reduction, Portuguese CKD patients with chronic metabolic acidosis could benefit from drinking *Frize*®, *Pedras Salgadas*® or *Vidago*®, even at a stage of subclinical metabolic acidosis, with the added benefits of reducing their pill burden.

Disclosure of potential conflicts of interest: none declared

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