Introduction

The American Dietetic Association recommends that a healthy diet include 2,900 ml and 2,200 ml of fluids per day for men and women, respectively. These values apply to persons living a sedentary lifestyle and need to be increased with physical activity, consumption of caffeine and alcohol, and warmer environmental conditions. It is estimated that 1,000 ml of fluids are derived from solid foods with an additional 250 ml derived from the oxidation of these nutrients. This leaves a minimum deficit of 1,000 to 1,500 ml of fluids that must be derived from noncaffeinated, nonalcoholic beverages. Many Americans do not meet these requirements. Furthermore, "dehydration of as little as 2% loss of body weight results in impaired physiological and performance responses" (1). Chronic, mild dehydration can adversely affect the risk of several important diseases. Water consumption, in particular, has been shown to increase the risk of cancers including those of the breast, colon, and urinary tract (1,2). In addition, dissolved inorganic chemicals in drinking water, such as magnesium and calcium, have been linked to a reduced risk of cancer and myocardial infarction (3,4).

While chronic, mild dehydration correlates with reduced cancer risk, many drinking water contaminants are blamed for increased cancer risk. Two of the most prominent contaminants are arsenic and the by-products of chlorination treatment (5). Both arsenic and trihalomethanes, by-products of the chlorination process, are found at reportable levels in the Los Angeles area drinking water supply (6). This poses a dilemma because people need to maintain a healthy level of hydration but also must avoid these common drinking water contaminants. Bottled water seems like a logical solution to the problem of purity. Recent studies of bottled water purity, however, actually show increased levels of both arsenic and trihalomethanes and decreased levels of magnesium and calcium that could correspond to an increased cancer risk (7,8).

Beneficial effects of drinking water and dissolved inorganic constituents

Adequate consumption of drinking water has been shown to have beneficial effects on "the risk of urinary stone disease; cancers of the breast, urinary tract, and colon; childhood and adolescent obesity; mitral valve prolapse; salivary gland function; and overall health in the elderly" (1). For example, one study in particular, published by Shannon, et al., showed that drinking more than four glasses of water per day correlated with a decreased risk of colon cancer. In this study, 424 men and women diagnosed with colon cancer were compared to 414 controls selected through a random digit telephone dialing method. The two populations were given an 80-item dietary questionnaire that examined both solid food intake and water consumption. Women who consumed more than five glasses of water per day compared with those who consumed two or fewer glasses of water per day had a decreased risk of developing colon cancer. Men showed similar results. Men who consumed more than four glasses of water per day compared to those who consumed one glass of water per day showed a decreased colon cancer risk (2). These preliminary data indicate that drinking water may indeed reduce colon cancer risk. A more comprehensive study with matched controls may prove more illuminating.

Several other studies indicate that the dissolved inorganic constituents of drinking water, particularly magnesium and calcium, may be beneficial to a person's health. Water hardness is an indicator of total dissolved magnesium and calcium; hard water has a correspondingly high content of these inorganic minerals. In one study, 883 Taiwanese who died of pancreatic cancer were matched with 883 controls by sex, year of birth, and year of death. Investigators then determined the hardness levels of the drinking water consumed by all 1766 Taiwan residents. The inhabitants whose water supply was derived from a soft water source (low Mg2+, Ca2+) showed a 39% increased risk of death by pancreatic cancer (3). In another study, the relationship between water hardness and death from acute myocardial infarction (MI) was examined. Researchers compared 378 women who died from acute MI with 1,368 controls who died from cancer in southern Sweden. They then compared these deaths to individual water supply concentrations of magnesium and calcium. Water supplies containing greater than 9.9 mg/l magnesium and 70 mg/l calcium conferred a reduced risk of death by acute MI (4).

As a side note, the Los Angeles area water supply averages 6.1-26.0 mg/l magnesium and 23.8-66.0 mg/l calcium depending on the actual water source. The LA Aqueduct Filtration Plant, which services UCLA and surrounding areas, produces the softest water in the Los Angeles area with 6.1 mg/l magnesium and 23.8 mg/l calcium (6). Based on these studies, this water would confer the least protective advantage against death by pancreatic cancer or acute MI. Bottled waters also seem to vary in dissolved magnesium and calcium content. One study showed that bottled waters ranged from 0-126 mg/l magnesium and 0-546 mg/l calcium. Also, the mineral content is rarely, if ever, reported by the water manufacturer (8). Due to this variability, it is difficult to be aware of and to benefit from the protective effects of magnesium and calcium in drinking water.

Arsenic in drinking water: an increased cancer risk?

Arsenic is a common pollutant found in drinking water throughout the United States. Arsenic has been linked to an increased risk of liver, lung, bladder, and kidney cancer (5). In one study, high levels of arsenic in a Northern Chilean water source increased the risk of death by lung and bladder cancer. In the water supply studied, arsenic concentrations reached as high as 570 m g/l eventually declining to 100 m g/l through implementation of water quality controls. During the four year period examined, lung and bladder cancer death rates were elevated and could not be explained by other factors such as smoking incidence. Researchers estimated that as much as 7% of all deaths (30 years old and up) in the region could be explained by lung and bladder cancer caused by arsenic poisoning (9). Other studies based in Taiwan of arsenic exposure through drinking water have shown similar results. However, the Taiwanese study was criticized because cancer rates could have been explained by "host and environmental factors not applicable elsewhere" (10). The Chilean study refutes this criticism and indicates that at high levels of arsenic exposure there is an increased cancer incidence.

Studies of transgenic mice have revealed a possible mechanism for arsenic-induced cancer. In a particular strain of transgenic mice (Tg.AC) treated with a low dose of tetradecanoyl phorbol acetate (TPA), increased skin papillomas occur in mice receiving

arsenic in their drinking water compared with TPA treated mice alone. Previous studies indicating that transforming growth factor (TGF)-alpha promotes skin tumor formation lead these researchers to hypothesize that arsenic may increase production of TGF-alpha. Cultures of primary human keratinocytes stimulated with micromolar concentrations of arsenic showed increased proliferation as a consequence of growth factor production. Furthermore, examination of human tumors obtained from people chronically exposed to arsenic in drinking water showed an increased expression of TGF-alpha. These results seem to indicate that micromolar concentrations of arsenic in drinking water increase TGF-alpha expression leading to tumor cell proliferation (11).

Current Food and Drug Administration (FDA) guidelines require that drinking water contain no more than 50 m g/l of arsenic (6). It is still not clear whether this micromolar concentration of arsenic is safe. Some have argued that "the cancer dose-response curve may not be linear at the lower exposures" of arsenic (10). Reports are conflicting, however, especially in light of the conclusive evidence of cancer incidence and high-dose arsenic exposure. Public health researchers are calling for an increase in attention to low-dose arsenic exposure to determine "if the dose-response relationship at low levels is more consistent with the current assumption of low-dose linearity or the existence of a practical threshold" (12). Indeed many researchers have taken this recommendation to heart and are examining the effects of low-dose arsenic exposure. One study in New Hampshire is examining the effects of arsenic exposure in the range of 10-50 m g/l on the rate of skin and bladder cancer. Preliminary results suggest that there is a 2-fold increased of bladder and skin cancer when subjects are exposed to arsenic concentrations near 50 m g/l (13). Another study centered in Belgium conflicts with the New Hampshire study. The Belgian study found that moderate exposure of arsenic in drinking water (20-50 m g/l) "did not enhance the mortality by diseases of the nervous system, liver and heart, and cancers" (14).

The Los Angeles Aqueduct Filtration Plant that services UCLA produces water with an average of 4 m g/l arsenic, which is well below the FDA mandated maximum of 50 m g/l (6). From the evidence presented, it seems that this level of arsenic is not likely a major cause of cancer in the Los Angeles area. However, some bottled waters have been found to contain arsenic in excess of the 50 m g/l maximum. Bottled water companies are completely exempt from Food and Drug Administration rules if they are packaged and sold within the same state. Common bottled water companies in California including Crystal Geyser Alpine Spring Water, Vittel Mineral Water, and Appollinaris, were found to produce water containing arsenic at levels greater than 50 m g/l on repeated testing (7). This is alarming because California is thought to produce some of the cleanest bottled water in the country.

By-products of the chlorination process: evidence of increased cancer risk

Another significant contaminant in drinking water is derived from the chlorination process. Chlorination is an effective means of limiting the spread of infectious disease by reducing the levels of bacteria and parasites in water. The by-products of the chlorination process (CBPs), however, usually reported as trihalomethane concentration or chloroform

concentration, are blamed for an increased risk of bladder and colon cancer. In fact, this process can be blamed for as many as 5,000 bladder cancer cases and 8,000 rectal cancer cases per year in the United States (5).

In one study, researchers examined the dose-response relationship between chloroform levels in drinking water and the risk of colon cancer and all cancers combined. Investigators found a direct relationship between amount of chloroform in the drinking water and colon cancer risk. This study was rather comprehensive in that it included 28,237 women form Iowa that had multiple drinking water sources (15). In another study centered in Ontario, Canada, 696 people diagnosed with bladder cancer were compared to 1,545 controls. All subjects had at least 30 years of drinking water exposure information. The researchers discovered that people who were exposed to trihalomethanes at a concentration of 50 m g/l or more for 35 years had 1.63 times the chance of developing bladder cancer than those exposed for less than 10 years. This study indicates that long-term exposure to even low-dose CBPs may increase bladder cancer incidence (16).

The evidence clearly suggests that the drinking water chlorination process can increase the risk of both bladder and colon cancer. On average, the total trihalomethane concentration of the Los Angeles drinking water supply is 43 m g/l, below the FDA maximum of 100 m g/l (6). It is apparent from the Ontario study that even at concentrations in this range, increased cancer risk is likely. Again, bottled drinking water does not seem to be a reliable solution. Several California bottled-water companies consistently produce water with trihalomethane concentrations above industry standards. Some brands include Lady Lee Drinking Water, Private Selection Drinking & Purified Waters, and Safeway Drinking Water. Furthermore, these companies are not subject to FDA regulations and do not report these values on bottle labels (7).

What's next?

Current research indicates that an ideal water supply be high in dissolved magnesium and calcium and free from arsenic and chlorination by-product contamination. Current water supplies, such as those available to Los Angeles residents, prove deficient in many of these areas. Bottled waters are certainly not the solution as many are less regulated and more contaminated than what flows from the tap. A simple answer is not clear. More research in the area of long-term exposure to low-dose toxins needs to resolve the debate of whether these toxins have a linear relationship with disease risk or if there is a threshold at which the toxins cause disease. Furthermore, bottled waters should be put to the same stringent standards as civic water supplies. Perhaps if these companies were required to report water hardness and toxin levels, market forces would cause them to produce a cleaner product for health-conscious consumers. Given the fact that hydration is an important element of nutritional health, water sources must be free from contamination.

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