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Hypertension incidence after tap-water implementation: A 13-year follow-up study in the arseniasis-endemic area of southwestern Taiwan

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ABSTRACT

Hypertension is the leading cause of cardiovascular disease worldwide. Long-term arsenic exposure has been linked to increased risk for hypertension; however, little is known whether a previous exposure has lingering effects on hypertension after the exposure being reduced significantly for decades. The study cohort was established in 1990 in an arseniasis-endemic area of 3 villages — Homei, Fuhsin, and Hsinming in Putai Township located on the southwestern coast of Taiwan, where residents were exposed to artesian well water (median level = 700 to 930 μg/L) until early 1970s. The original cohort consisted of 490 non-hypertensive residents over 30-yrs-old and 352 of them were successfully followed up in 2002/03. Arsenic concentrations in the artesian well water consumed by residents during 1960s were used to indicate the previous exposure while urinary arsenic species measured in 2002/3 was used to represent current exposure. Hypertension incidences were 27.4, 65.6, and 69.1, per 1000 person-years for men aged 35–49, 50–64, and 65–74 years, respectively being higher than the corresponding rates of 25.1, 46.1, and 57.2 in a community-based longitudinal study. Cancer was the major cause of the total deaths (17/30 = 57%). Diastolic blood pressure was shown to increase with an increased cumulative arsenic ingestion from drinking water ($\beta = 0.27$, $p < 0.001$). The incidence was increased by 2.43-fold in subjects of As(V) ≥ 2.67 μg/g creatinine as compared to those of As(V) < 1.20 μg/g creatinine (the third vs. first tertile; $p = 0.047$) after adjustment for conventional risk factors. This study suggests that three decades after cessation of drinking artesian well water, residents of the endemic area are still at increased risk for developing hypertension, particularly those who excrete high amounts of As(V).

1. Introduction

Inorganic arsenic in groundwater is ubiquitous and raises global health concerns because of the increasing dependence on groundwater for daily intake (Smith et al., 2002). Arsenic contamination has been found in many countries in Southeast Asia, North America, South America, and Europe (Nordstrom, 2002). Arsenic in drinking water has been found to be associated with an increased prevalence of hypertension (Chen et al., 1995), cardiovascular disease (Tseng et al., 2003; Tseng, 2008), cerebrovascular disease risk (Wang et al., 2002) and other conditions, including renal disease and neurological dysfunction (Wang et al., 2003). We are particularly interested in evaluating the remaining risk for an increased incidence of hypertension following a substantial reduction in arsenic ingestion after introduction of treated tap water to arseniasis-endemic communities.

Hypertension is recognized as a major risk factor for a number of diseases (Kannel, 1996), including stroke (Hu et al., 2005), ischemic heart disease (Rodgers et al., 2000; Mehler et al., 2003) and end-stage renal failure (Iseki et al., 2000). Hypertension prevalence and incidence have both been shown to be increasing worldwide (Ueshima et al., 2000; Callow, 2006). Preventing hypertension would in turn prevent its associated vascular complications and related heath-care costs (Rodgers et al., 2000; Mehler et al., 2003).

Abbreviations: As, arsenic; As(III), arsenite; As(V), arsenate; BMI, body mass index; CV, coefficient of variation; DMA, dimethylarsinic acid; HDL, high density lipoprotein; HPLC, high-performance liquid chromatography; LDL, low density lipoprotein; MMA, monomethylarsonic acid; TRG, triglycerides; RR, relative risk; SMR, standardized mortality ratio.

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Arsenic in drinking water may soon join obesity, cigarette smoking, and salt intake as an important modifiable lifestyle factor that can be altered in an effort to prevent cardiovascular disease. Important risk factors of hypertension include age, obesity, cigarette smoking and male gender, which need to be considered (Lindberg et al., 2008).

Local residents of an arseniasis-endemic area in southwestern Taiwan relied on artesian wells as the major source of drinking water between 1910 and 1970 (Lo et al., 1977). A median arsenic concentration of the artesian well water in this area ranged from 700 to 930 μg/L. A treated tap water supply system was implemented in this area starting from late 1960s and completed in early 1970s, replacing artesian wells as the source of drinking water. Arsenic level of drinking water in the area has been monitored routinely ever since and the level was substantially reduced to meet the regulatory guideline of 10 μg/L set by Taiwanese government. To evaluate changes in hypertension risk, we followed a geographically stable population with documented previous ingestion of arsenic from artesian well water (Chen et al., 1995). This 13-year (1990–2003) follow-up cohort provides a unique opportunity to assess hypertension occurrence two to three decades after high arsenic exposure, with conventional risk factors being considered.

2. Materials and methods

2.1. Study area and population

The Human Ethical Committee of the National Health Research Institutes of Taiwan approved this study protocol. Before participation, each subject provided informed consent after receiving a detailed explanation of the study and its potential consequences.

Subjects were from a community-based cohort established by Chen et al. (1995) in 1990 from three villages — Homei, Fuhsin, and Hsinming in the Budai Township, which is located on the coast of southwestern Taiwan (Fig. 1). Budai Township had a high (9.6%–13.6%) prevalence of blackfoot disease (Lin et al., 1998) and a median arsenic concentration in its artesian well water ranging from 700 to 930 μg/L (Kuo, 1964; Chen et al., 1995). Due to the lack of tap water and high salinity of shallow well water in this coastal region, local residents relied on artesian wells as the major source of drinking water until early 1970s. A tap water supply system was implemented in this area starting from late 1960s and completed in early 1970s, replacing artesian wells as the source of drinking water. When the use of artesian well water peaked between 1950s and 1970s, many blocks in the study area had several artesian wells available within about 350 m of walking distance. Arsenic level of tap water in this area was monitored under the current Taiwanese guideline of 10 μg/L, the same level recommended by the World Health Organization. Arsenic exposure level through drinking water in this area was therefore reduced to as much as 1–1.4% of the previous exposure (10 vs. 700 or 930 μg/L).

Initially, 1571 subjects over the age of 30 were interviewed in 1988–89. Each subject was a registered resident at the local household-registration office and lived at least 5 days a week in the three study villages (Chen et al., 1995). A total of 898 residents participated in health examinations, including cardiovascular disease risk assessments (i.e. blood pressure, serum cholesterols and triglycerides) in 1989–90 (Fig. 2). A cohort of 779 residents who had both blood pressure record and valid contact address were studied. We excluded 289 subjects diagnosed with hypertension and investigated the 490 non-hypertensive subjects. Subjects were invited for health checkups in 1993, 1996, and 2002/03. By 2002/03, 382 (78%) of these subjects were successfully followed and 138 had been lost to follow-up because they were untraceable (i.e. changes in their national-identification numbers) or had refused to be followed. In order to maximize the follow-up person-years, we utilized hypertension and related data collected at 1989–90 (baseline) and 2002–03 (follow-up). However, if the subjects were not followed in 2002–03, we used the data collected in 1996. Similarly, if again not followed in 1996, then we adopted the data in 1993. A total of 779 subjects were

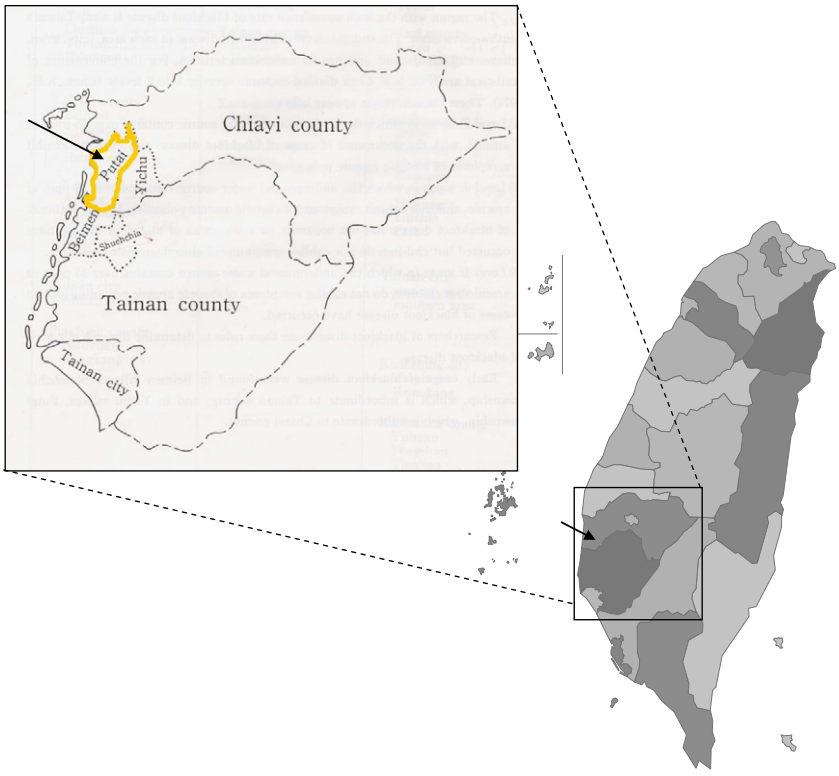

Fig. 1. Map of the study area shown in yellow boundary located in southwestern coast Taiwan.