Health & Place 22 (2013) 115–122

Contents lists available at SciVerse ScienceDirect

Health & Place

journal homepage: www.elsevier.com/locate/healthplace

The contextual influence of coal abandoned mine lands in communities and type 2 diabetes in Pennsylvania

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ARTICLE INFO

Article history:
Received 24 November 2012
Received in revised form
11 March 2013
Accepted 31 March 2013
Available online 25 April 2013

Keywords:
Context
Coal
Abandoned mine lands
Diabetes
Multilevel

ABSTRACT

Coal abandoned mine lands (AMLs), persistent and prevalent across Pennsylvania, offer an instructive evaluation of potential contextual influences of chronic environmental contamination (CEC) on individual health. We evaluated associations between the burden of AMLs, represented by 10 contextual metrics at the community level, and individual-level type 2 diabetes using hemoglobin A1c (HbA1c) as a biomarker. Cross-sectional and longitudinal multilevel analyses were conducted with over 28,000 diabetic primary care patients of the Geisinger Clinic. Adjusted models revealed five AML burden measures were associated ($p < 0.05$), and three additional were borderline associated ($0.05 \leq p \leq 0.10$), with higher and/or change in HbA1c levels. This study provides key empirical evidence of adverse impacts of CEC in communities on an important chronic disease, illustrating the contextual effects of living in long-term degraded landscapes and communities.

1. Introduction

Pennsylvania has a heavy burden of abandoned coal mines (hereafter termed abandoned mine lands [AMLs]), a third of all AML sites in the United States (Legacy, 1997). AMLs are an example of chronic environmental contamination (Couch and Coles, 2011), an emerging public health issue with few formal evaluations of health impacts despite widely recognized concerns about the potential for adverse effects. The burden of AML in communities has been shown to be associated with greater socioeconomic deprivation and social disorganization (Liu et al., 2012), which has been linked to adverse individual health outcomes, including kidney and cardiovascular diseases (Augustin et al., 2008; Chaix et al., 2007; Cubbin et al., 2000; Diez Roux et al., 1997, 2001, 2004; Dragano et al., 2007; Lisabeth et al., 2007; Merkin et al., 2005; Shoham et al., 2007, 2008; StjäRne et al., 2006; Sundquist et al., 2004; Ward, 2008). Diabetes is of particular interest because it is a common, costly, and chronic progressive disease (Barker et al., 2011) that has several behavioral risk factors that are influenced by the built and social environments and may be subject to long-term impacts from chronic environmental contamination (Parks et al., 2003). Moreover, disease progression is often assessed by measuring levels of hemoglobin A1c (HbA1c), a well-validated, common clinical management biomarker of diabetes (Caveney and Cohen, 2011; Larsen et al., 1990).

Research on environmental determinants of diabetes has shown that residing in a deprived neighborhood is associated with an increased prevalence of type 2 diabetes (Andersen et al., 2008; Chaix et al., 2011; Connolly et al., 2000; Cox et al., 2007a, 2007b; Evans et al., 2000; Geraghty et al., 2010; Hazuda et al., 1988; Hippisley-Cox et al., 2004; Krishnan et al., 2010; Larrañaga et al., 2005; Long et al., 2010; Millett et al., 2007; Schootman et al., 2007; Wild et al., 2008). The Appalachian region, known for its extensive history of coal mining, has high levels of socioeconomic disadvantage (Hendryx and Ahern, 2009) as well as high prevalence of diabetes and cardiovascular morbidity and mortality (Hendryx, 2009; Hendryx and Ahern, 2009). Studies on current coal mining and the health of surrounding populations in these

Abbreviations: AML, abandoned mine lands; CT, census tract; MCD, minor civil division; RAMLIS, reclaimed abandoned mine land inventory system; SMCRA, Surface Mining Control and Reclamation Act.

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http://dx.doi.org/10.1016/j.healthplace.2013.03.012

areas suggest that residential proximity to high levels of coal production contributes to a higher burden of diabetes, kidney disease, cardiopulmonary disease, cardiovascular disease, and lung disease (Hendryx and Ahern, 2008; Hendryx, 2009). AMLs are a consequence of a long history of natural resource extraction and are persistent and prevalent across Pennsylvania, making them an excellent example of chronic environmental contamination, enduring exposures of perceived or known anthropomorphic origin, that could influence health through contextual impacts, particularly through psychosocial stress pathways (Couch and Coles, 2011).

To evaluate the hypothesized associations among AMLs, community context, and diabetes, we capitalized on the wealth of longitudinal data available in the electronic health record (EHR) of the Geisinger Clinic in Pennsylvania. Since 2001, comprehensive data including sociodemographic information, vital signs, ICD-9 codes, laboratory results, medications, and procedures for clinical encounters have been captured by the EHR. Data were available on approximately 450,000 patients with a Geisinger primary care provider from over 40 community practice clinics during this time period. This wealth of data provided information on individual-level diabetes outcomes, including multiple measures of HbA1c, a well-validated biomarker of diabetes.

Chronic environmental contamination in communities could influence health through several mechanisms, particularly by modifying stress pathways and health-related behaviors (Couch and Coles, 2011; Mcewen and Tucker, 2011). Specifically, AMLs could contribute to daily psychosocial stress and overly tax the stress response system (Couch and Coles, 2011; Mcewen and Tucker, 2011) of residents who encounter AMLs in their communities on a daily basis (Mcewen and Tucker, 2011). This persistent exposure to chronic environmental contamination could lead to metabolic dysregulation and worsening of diabetes. AMLs also could influence health-related behaviors, by inhibiting physical activity in communities with visible abandoned mines, for example. These hypotheses suggest that a chronic disease such as type 2 diabetes would be a very appropriate first evaluation of the individual health impacts of community chronic environmental contamination.

2. Methods

2.1. Study population and design

The study population consisted of 24,122 primary care patients of the Geisinger Clinic who represent the general population (unpublished data) in Geisinger's core primary care market of 31 counties in central and northern Pennsylvania. Inclusion criteria required: (1) a residential address within the 31 counties; (2) a diabetes ICD-9 code (250.xx) on the problem list or at least two outpatient encounters with the code; (3) at least two HbA1c measurements; and (4) at least 30 years of age at the time of the first-ever HbA1c measurement to efficiently exclude type 1 diabetes, which was not thought to be related to AMLs in communities.

2.2. Data sources and collection

Details on the creation of the community-level burden of AML exposure variables, covariates, and three dimensions of community context have been previously reported (Liu et al., 2012). In brief, prior to examining hypothesized associations, 10 measures of AML burden were created from data in the Reclaimed Abandoned Mine Land Inventory System (RAMLIS) and included seven measures of the density of AMLs, a measure of accessibility based on a gravity model (Kockelman, 1997), a diversity measure, and a measure of the extent of clustering of AML sites (Selvin et al., 1993). Esthetic quality features referred to the attractiveness of landscapes, and the density measure was calculated as the count of dry strip mines, flooded strip mines, and abandoned structures and equipment divided by the area of the community. The density of physical hazards, threats that had the potential to cause bodily harm, was calculated as the count of high walls, open mine shafts, subsidence prone areas, and vertical mine shafts divided by the area. The density of toxic contamination that stemmed from various sources throughout abandoned mine sites was calculated as the count of acid mine drainage discharges, refuse piles, spoil piles, and untreated discharges divided by the area. The Surface Mining Control and Reclamation Act (SMCRA) of 2006 defines AML problems as priority areas that pose a threat to health, safety, and general welfare of people (i.e., priority areas 1 and 2) or to the environment (i.e. priority 3). Therefore, the density of priority 2 areas and priority 3 areas, but not priority 1 areas which were too few in number, were included to evaluate this strategy of categorization. Potential community-level confounders included median age, proportion male, proportion non-white, proportion Hispanic, proportion urban, population density, proportion current mining occupation, and density of active coal mines.

Individual-level variables including baseline age, sex, race/ethnicity, residential location, weight, height, HbA1c measures, and medications were obtained from the Geisinger EHR for the years 2001–2010. For individual-level measures of diabetes as the health outcome, we first considered using fasting blood glucose measurements because these are routinely measured in primary care. However, there was no method to distinguish fasting from other blood sugar measures available from over 400,000 blood glucose measurements in the laboratory results. Therefore, we used HbA1c as the primary outcome. On average, diabetes patients had more than 10 HbA1c measures in the EHR. The rich longitudinal data allowed us to evaluate the temporal relations among these measures (Fig. 1) and to conclude that many patients were treated for diabetes prior to the appearance of an ICD-9 code for diabetes in the medical records. We thus used as outcomes in the analysis (1) the first HbA1c measure after the first diabetes ICD-9 code as an encounter diagnosis (termed DIAGNOSED-HbA1c) from 17,959 geocoded patients and (2) the first HbA1c measure before any treatment for diabetes (termed MED-FREE-HbA1c) from 7337 geocoded patients. We used the diagnosed-HbA1c to identify the maximum number of patients with a HbA1c regardless of medication usage to try to capture the largest sample size of diabetics in the patient population. However, these HbA1c levels would be substantially affected by diabetes medication, and we believed any possible associations with AML burden in communities would be relatively small in relation to the very strong effects of medication use and thus be masked in our analyses. Therefore, in order to optimize the chances of detecting associations with chronic environmental contamination, we evaluated med-free-HbA1c.

2.3. The definition of community and the study area

In research to evaluate compositional and contextual effects (Diez Roux, 2001), having an experientially relevant definition of community, one that appropriately captures the geographic, social, and cultural space significant to residents, is important. For this purpose, we used a mixed definition of community using *minor civil division* boundaries in townships and boroughs and *census tract* boundaries in cities as described in a previous study (Schwartz et al., 2011a). Analysis was restricted to communities with at least 10 patients residing within their boundaries. For the analysis of diagnosed-HbA1c and med-free-HbA1c levels, the study area was composed of 412 (279