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In Collaboration with:

Desert Sierra Cancer Surveillance Program
Region 5 of the California Cancer Registry
Cancer Registry of Greater California

Comprehensive Cancer Assessment in Hinkley, California: Did Erin Brockovich Get It Right?

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Background: Inhaled chromium 6 [Cr(VI)] powder is an accepted cause of nasopharyngeal and lung cancer in humans, while carcinogenicity of aqueous Cr(VI) remains unclear. The Desert Sierra Cancer Surveillance Program (DSCSP), part of the Cancer Registry of Greater California, covers San Bernardino and three other counties. The DSCSP serves 4.1 million California residents. Together with nine other registries, the DSCSP forms the California Cancer Registry (CCR). All cancers diagnosed in California since 1988 have been reportable to the CCR, part of the Surveillance Epidemiology and End Results (SEER) program. Information reported to CCR includes precise cancer type, stage, date, residence at diagnosis, and demographic characteristics.

Problem: A widely publicized legal settlement, movie (*Erin Brockovich*), and numerous news stories portrayed a cancer excess in Hinkley. In 1997, 2000,[1]and 2010,[2] the DSCSP completed preliminary studies that did not identify a cancer excess in the Hinkley tract. The comprehensive findings, reported here, extend DSCSP findings for all cancers by including 19 cancer subtypes and adjusting for outmigration during the study.

Methods: A literature review identified cancers potentially associated with Cr(VI). Other malignancies were also included because of potential sensitivity to environmental exposures and to represent an array of cancer types. Data for individuals diagnosed with cancer in the CCR database were extracted by the DSCSP for 1996-2008. The geographic assessment area was the Census tract encompassing Hinkley and the surrounding area (Hinkley tract). Observed new cancers were identified by residence at diagnosis in the Hinkley tract classified by 19 age-categories (<1; 1-4, 5-9, 10-14, 15-19, … 80-84, and 85+ years), sex, and race/ethnicity (Asian/Other, Hispanic, non-Hispanic black, and non-Hispanic white).

Average annual Year 2000 incidence rates were formed by dividing new cancer counts in the DSCSP for 1998-2002 in each of the 152 unique demographic categories by corresponding DSCSP denominators. These demographic factor-specific, average annual incidence rates were multiplied by the proportional distribution of the Hinkley tract population in each of the same 152 demographic categories, with the sum of the products multiplied by the tract population size (indirect standardization). The expected number of new cancers computed for Year 2000 was multiplied by weights representing proportions of the Year 2000 population during each of the 13 years assessed using methods developed by the investigators in a previous study.[3] Summing annual expected counts for the 13-year study yielded the number of new cancers expected if the Hinkley tract experienced the DSCSP average cancer risk for the demographic features of the tract. Standardized incidence ratios (SIR) were calculated for all cancers and 19 specific cancers by dividing observed numbers by expected counts. Estimates of lower and upper 95 percent CI limits were computed using an equation based on the Poisson distribution.[4] Data analyses used SEER*Stat, Microsoft Excel, and SAS.

Results: Census 1990 identified 3,870 residents in the Hinkley tract, with a decline to 3,644 in Census 2000 (Table 1). Median age for the tract in 1990 and 2000 was 45-49 years; like the tract, county, DSCSP, and state during 2000. The female proportion of the Hinkley tract population was 49.5 percent in 1990 and 2000 and was 50.2 percent in the DSCSP and California in 2000. The Asian/Other and Hispanic proportions increased from 1990 to 2000 in the Hinkley tract, while the non-Hispanic black proportion remained constant and non-Hispanic white. percent decreased (Table 1).

Table 1. Counts and percent of total population (% Total) according to sex and race/ethnicity characteristics of the Hinkley Census tract in 1990 and 2000 and for the DSCSP and statewide populations for Census 2000. Data from the California Cancer Registry.

	Hinkley Census Tract				DSCSP		Statewide	
	Census 1990		Census 2000		Census 2000		Census 2000	
Sex	Count	(% Total)	Count	(% Total)	Count	(% Total)	Count	(% Total)
Males	1,958	(50.6%)	1,840	(50.5%)	1,637,056	(49.8%)	16,838,698	(49.8%)
Females	1,912	(49.4%)	1,804	(49.5%)	1,647,119	(50.2%)	16,993,888	(50.2%)
Race/Ethnicity								
Asian/Other	123	(3.2%)	201	(5.5%)	245,126	(7.5%)	4,904,014	(14.5%)
Non-Hispanic Black	96	(2.5%)	85	(2.3%)	242,236	(7.4%)	2,171,762	(6.4%)
Hispanic	661	(17.1%)	921	(25.3%)	1,233,214	(37.6%)	10,954,814	(32.4%)
Non-Hispanic White	2,990	(77.3%)	2,437	(66.9%)	1,563,599	(47.6%)	15,801,996	(46.7%)
Total	3,870	(100.0%)	3,644	(100.0%)	3,284,175	(100.0%)	33,832,586	(100.0%)

Table 2 presents 1990 and 2000 population counts and projections (2005 & 2010) estimating the Hinkley tract population for 1996-2008. A 10.6 percent decline in tract population size was measured from 1996-2008. Weights representing proportions of the Year 2000 population were used to adjust annual expected counts for population contraction during the study period.

Table 2.Population size for 1990, 2000, 2005, and 2010, annual population estimates for 1996-2008 computed using fitted linear regression for Census population estimates and weights representing the proportion of Year 2000 population size for each year in the assessment.

Year	**1990**	1996	1997	1998	1999	**2000**	2001	2002	2003	2004	**2005**	2006	2007	2008	**2010**
Census Population Estimate*	**3,870**					**3,644**					**3,340**				**3,290**
Regression Annual Population Estimate†		3,699	3,668	3,637	3,606	3,575	3,544	3,513	3,482	3,451	3,420	3,389	3,358	3,327	
Annual weights computed as the proportion of the 2000 population‡		1.02	1.01	1.00	0.99	**1.00**	0.97	0.96	0.96	0.95	0.94	0.93	0.92	0.91	0.90

* Population estimate from the Year 1990 Census, Year 2000 Census, and for 2005 and 2010 Claritas.
† Annual population estimate computed from linear regression using Census estimates for 1990, 2000, 2005, and 2010. The linear regression equation is $y = -30.994x_i + 3915.7$; where x_i is integer counts of 7-19 representing study years 1996-2008.
‡ Weights used to adjust annual population counts as the proportion of the Year 2000 population.

Table 3 presents observed and demographic factor adjusted expected counts of new cancers, SIRs, and 95 percent CI for SIRs aggregated for 1996-2008 for invasive cancer and each of 19 cancer types.

Table 3. Aggregated observed† and adjusted expected† cancer counts, standardized incidence ratios (SIR), and 95 percent confidence interval limits (95% CI) for all cancers and 19 selected cancers from 1996-2008 in Hinkley tract. Data from the California Cancer Registry.

Cancer Site	**Observed**	**Adjusted Expected** §	**SIR**	**95% CI‡ for SIR**
All cancer Sites (combined)	196	216.42	0.91	0.78, 1.04
Nasopharyngeal carcinoma	0	0.21	<1	undefined
Respiratory	38	32.97	1.15	0.82, 1.72
Lung & bronchus	34	30.12	1.13	0.78, 1.58
Digestive	29	40.55	0.72	0.48, 1.03
Oral cavity & oropharynx	<5	>5	0.38	<0.10, 1.38
Esophagus & stomach	7	5.21	1.34	0.53, 2.79
Intestine (small intestine & colorectal)	18	22.71	0.79	0.47, 1.26
Liver & intrahepatic bile ducts	<5	<5	0.74	<0.10, 2.73
Pancreas	0	5.00	<1	undefined
Prostate gland	22	34.11	0.65	0.40, 0.98
Urinary bladder	5	9.25	0.54	0.17, 1.27
Kidney & renal pelvis	5	5.30	0.94	0.30, 2.22
Cervix (*cervix uteri*)	7	2.48	2.83	1.12, 5.86
Breast	27	34.52	0.78	0.51, 1.14
Cutaneous melanoma	6	9.81	0.61	0.22, 1.34
Hematopoietic system	20	16.86	1.19	0.72, 2.04
Brain & other nervous system	<5	<5	0.68	<0.10, 2.49
Thyroid gland	<5	<5	0.34	<0.10, 1.97
Childhood cancer (age <20)	5	2.44	2.05	0.65, 4.82

† Counts fewer than 5 are presented as <5 and greater than 5 as >5 to ensure confidentiality.
§ Expected counts adjusted for age, sex, race, ethnicity, population size, and contraction of the Hinkley population.
‡ Lower CI limits near zero are presented as <0.10.

Table 4 includes findings that compare the Hinkley tract, San Bernardino County, and California populations for selected socioeconomic status (SES) variables reported in Census 2000.

Table 4. Comparison of median household income, median family income, percent of adults that earned either bachelor's or graduate/professional degrees for the Hinkley tract, San Bernardino County, and California reported in the Year 2000 Census. Ninety-five percent confidence interval limits (95% CI) are for the Hinkley tract for education variables. Economic variables from Year 2000 Census.

	Hinkley Census tract	San Bernardino County	California (Statewide)
Median household income in 1999 (P53) ($)	39,637	42,066	47,493
Median family income in 1999 (P77) ($)	44,857	46,574	53,025
Highest attained adult education in 2000 (P37)			
Percent of population older than age 25 years			
with bachelor's degrees (95% CI)	5.26 (4.55, 6.05)	6.86	11.29
with graduate/professional degree (95% CI)	2.47 (1.99, 3.04)	3.64	6.30

Interpretation: Findings are consistent with previous investigations by the DSCSP for the Hinkley tract that found no cancer excess.[1-2] Only cervical cancer demonstrated an observed count above the level reasonably attributed to sampling error. Occurrence of cervical cancer is substantially determined by human *papallomavirus*, a sexually transmitted agent, with cases representing failure to detect and treat premalignant cervical dysplasia.[5] Together with fewer than expected counts of prostate cancer, these findings portray underutilization of early detection resources for these cancers in the lower than average SES and geographically isolated desert community. An *a posteriori* review of CCR data revealed that 33 percent of the new colorectal cancer cases in this study were diagnosed at advanced stage, compared to 18 percent for in the county, DSCSP, and state during the study period. These findings support our assertion that the Hinkley tract population is underserved for early cancer detection.

Our findings identified a slightly higher count of respiratory cancer, including lung and bronchus, than the expected number. Lower SES predicts higher than average tobacco use, the principle risk factor for lung and bronchus and other respiratory cancers.[5] Our study did not measure tobacco use, although it is reasonable to surmise that smoking may have been more prevalent than average in the lower SES[5], Hinkley population.

Failure to identify a digestive cancer excess and absence of pancreatic cancer allays concerns that an alimentary cancer excess occurred in the Hinkley tract. Absence of nasopharyngeal carcinoma, lower counts than expected for all cancers combined and for many other cancers, and failure to identify a statistical excess for any cancer, other than *cervix uteri*, counters claims that a generalized cancer excess occurred in the Hinkley tract during the study.

The Year 2000 Hinkley tract population represents about 0.10 percent of the DSCSP population. The relatively small size of the Hinkley tract population ensures substantial independence between the observed and expected counts. Our study included methods developed in an earlier investigation that adjust annual counts of expected new cancers as the size of the population in the study area changed.[3]

Limitations: The paucity of observed counts for some cancers limits the statistical power available to fully characterize findings. In contrast, observed counts for pancreas and prostate cancers included sufficient power to report significant deficits in counts, and a significant excess for cervical cancer.

It is possible that former residents of the Hinkley tract may have been exposed to Cr(VI), moved out of the area, and were diagnosed with cancer while residing elsewhere. Findings in this study are consistent with those reported by the DSCSP for 1988-1993 and 1988-1998,[1] when the size of the Hinkley tract population was relatively static (Table 2). Methods used in this study adjusted for contraction of the Hinkley tract population, but may not have completely eliminated effects of selective outmigration of former Hinkley residents. Failure to include previous Hinkley residents that moved elsewhere would tend to bias SIR findings toward the null hypothesis value of unity, rather than below the null, as found for many cancers. Changes in the race/ethnicity distribution of the Hinkley tract population were not adjusted in this study, but are believed to be inconsequential.

Our study did not measure Cr(VI) in the Hinkley tract and does not distinguish between cancers that occurred among residents of the town and the tract. Neither does our study distinguish between residents exposed to Cr(VI) and those having no exposure, nor does it assess non-cancer health outcomes. Rather than assessing the role of aqueous Cr(VI) as a human carcinogen, these findings add to previous evidence that a cancer excess has not occurred among residents of the Hinkley tract for all cancers, extending this finding to include 18 cancer types.

Conclusions: Cancer occurrence in the Hinkley tract is consistent with that seen in the DSCSP and statewide, considering the unique demographic and population contraction characteristics of the tract. The combined observations of a higher number of cervix and significantly lower occurrence of prostate cancers than expected, combined with delayed colorectal cancer diagnosis in the Hinkley tract is sufficient to encourage enlarged cancer screening efforts in remote desert communities, like Hinkley.

References:

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