Case-Control Study of Brain Cancers in a Texas City, Texas Chemical Plant

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Twenty-three employees of a chemicals and plastics plant had death certificate diagnoses within the rubrics "malignant neoplasm of the brain" (7th Rev. ICDA 193), "benign neoplasm of the brain" (7th Rev. ICDA 223), and "unspecified neoplasm of the brain" (7th Rev. ICDA 237). A cohort mortality study has shown an overall standardized mortality ratio for benign, malignant, and unspecified neoplasms of the brain, based on the white males, of 160, with the SMR for those with greater than 15 years of work at the plant 280[1]. This nested case-comparison study used six controls per case to examine job title, departmental employment history, chemical exposure history, geographic location within plant, dates of employment, and home address, seeking associations which might explain the occurrence. Since the technique used involves multiple significance testing, chance associations are very likely, and caution must be used in interpreting results which appear to be statistically significant. The greatest apparent risks were associated with exposure to carbon dioxide, ethylene, sulfuric acid, and vinyl acetate; with first employment in the 1940's or early 1950's; and with residence in La Marque, Texas. Only the association with La Marque residence was strong enough to seem plausible.

No association was found with exposure to vinyl chloride monomer (VCM), although VCM has been implicated in etiology of brain tumors before and was produced and used at this plant for many years.

Introduction:

Late in 1978, a worker at a chemicals and plastics plant in Texas City, Texas notified the Houston South Area Office of the Occupational Safety and Health Administration (OSHA) of an apparent cluster of four brain tumors among employees and former employees of the plant. The local OSHA staff conducted preliminary inquiries and, in February, 1979, the National Institute for Occupational Safety and Health (NIOSH) and OSHA, with the aid of the company management, began an investigation of the cluster. Alexander[2] et al. have described the characteristics of the brain tumor cases and the methods for case identification. A final report on a cohort mortality study of all causes of death is in press[1]; findings included an overall standardized mortality ratio (SMR=100[observed/expected]) among white males for benign, malignant, and unspecified neoplasms of the brain of 160, while for those employees with greater than 15 years of work at the plant, the SMR was 280. We here describe a nested case-control study of primary brain tumor cases among employees of that plant .

The plant is an open-air facility covering several acres. It was opened in 1941 and has undergone a number of additions since then, as described elsewhere[1].

Methods and Materials:

Case Identification

A total of 23 possible cases were identified through several sources. The company identified 12 cases from death certificates obtained for medical surveillance purposes or for employee benefits program claims. The M.D. Anderson Hospital and Tumor Institute, using Texas Bureau of Vital Statistics records, generated lists of all adult males who were residents of surrounding counties and who died of malignant brain tumors between 1950 and 1977; these were then matched with company employment records, yielding four additional cases. Three additional cases became ill and died during the course of the study, and four cases were found in the course of completing the cohort mortality study. We were able to obtain medical records for 20 of the possible cases and tissue specimens were obtained for 10.

The Armed Forces Institute of Pathology (AFIP) reviewed the tissue specimens. Where different diagnoses were recorded for the same patient, AFIP reviews were ranked first, autopsy reports second, surgical pathology reports third, diagnosis from the hospital chart fourth, and death certificate diagnosis last; the highest ranked diagnosis was used for this study.

As Schoenberg advised, we initially included all deaths due to primary intracranial neoplasms except those of the pituitary. Six of these "cases" were excluded from the case-control study as outlined in Table I, leaving the 17 gliomas as the group of interest. Gliomas are carcinomas, arising from ectodermal tissue of the neural crest, while meningiomas arise from mesodermal embryonic tissue.

Selection of Comparison Subjects

For each case, a pool of potential controls was drawn from the set of all people ever employed at the plant. Selection criteria were: race and sex matched the case; year of birth was within three years of the case's; date of first hire at Texas City for the control was before that of the case, but year of first hire was not earlier than three years before the case's; the date the control was last employed was later than the case's last date of employment; the control, if dead, must not have died of a malignancy. Six controls were then drawn by random number from the pool of employees meeting these criteria. If the pool was large enough, three alternates were chosen for use if a control later died of cancer or was found to be otherwise ineligible.

Data Collection

For each present and former employee, the company completed coding sheets containing demographic data, date of each new job title or department code, job code, department accounting code, date of each layoff, date of termination, and vital status (when known). NIOSH independently verified the completeness of cohort identification and the accuracy of the coding.

The company provided translations for the job and department codes, indicated which department codes formed larger major department groups, and provided a list of chemicals used, produced, or redistributed in each department group. A "department group" is an operational unit of the plant manufacturing related products and within which employees often remained over fairly long periods. The departmental coding schemes used for accounting purposes within the plant have changed over the years, so a common list tracing the history of each department was prepared.

There appears to have been no problem in characterizing the feedstocks, outputs, and intermediate products of each department through the years the plant has been in operation. Since industrial hygiene data are available only for recent years and are not available for all compounds, we were forced to equate presence of a chemical in a department with worker exposure. This assumption was clearly not always accurate, nor were exposures necessarily equal in two departments using the same chemical.

For each job, department, major department group, or chemical exposure common to at least four cases, an odds ratio was calculated and tested for possible significance by the Mantel-Haenszel Chi, using the matched data programs of Rothman and Boice[4]. Since this approach was a multiple significance testing technique which should lead to about one "significant" association (at an alpha level of 0.05) for every twenty jobs, departments, or exposures considered, it is used here as a hypothesis-generating mechanism. Nearly 300 chemicals were present in the plant; chance alone could lead to identification of about 15 chemicals whose proportion is "significantly" different (higher or lower) between cases and controls at the $p = 0.05$ level. The probability values cited throughout the paper are given only to show relative strength of associations.

Only those portions of the controls' work experiences which occurred during the time the case was employed were considered in this analysis, since the matching criteria selected controls with longer total work histories than the cases'.

Duration of exposure was examined for four chemical exposures that were statistically significant in the analyses described above or which seemed of special importance based on previous reports. For those cases who had worked in departments other than maintenance, the total time of potential exposure was compared with the average time of exposure for the controls with work in non-maintenance departments. Both paired and unpaired t-tests were used.

It is possible that workers in a department nominally unexposed to a particular chemical could, in fact, be exposed to airborne vapors or dusts from an adjacent department; to assess this possibility, the years worked by each case or control in each department group were tabulated, showing which department groups had about a 1:6 ratio of case to control years, which groups had disproportionately more case years, and which had fewer. This information was plotted on a map of the plant, which was inspected for clusters.

If a brain tumor hazard were present in the past, but was later reduced or eliminated, times of first hire and employment spans may suggest a time "window" when a risk factor may have been present. The proportion of cases starting each year was compared with the proportion of all plant employees. Total work span of each case was graphed to see if there was a time with maximum overlap of work histories.

Non-work factors

In order to examine factors outside the work environment, the company provided all known home addresses for each case and for the first three controls for whom addresses were available. Most of the nearby communities had no residential mail delivery during the early 1940's, so only community of residence could be determined. Since past home addresses are not essential to personnel activities, the information retained by the company was incomplete. A case-location service was retained to determine historic

places of residence for the cases and controls and additional information was obtained through review of medical records retained at the plant. Communities in which cases had lived were tabulated and analyses were conducted for communities in which at least five cases had lived, using a division of "ever lived" vs. "never lived" in the community for periods 15 or more years before the death of the case, less than 15 years before the death of the case, and any time before the death of the case. Analysis of home address used all addresses between 1940 and the date of the case's death.

Results:

Demographics

Date of first hire of the comparison subjects averaged 18.0 ± 14.2 months before that of the cases, and the comparison subjects were, on average, 4 ± 24 months older than the associated case. While at least six controls were originally matched to each case, complete tabulations of departmental codes revealed that five controls had begun work at other plants owned by the company and had not come to Texas City until after the case started work; one control was found to have died of cancer. Alternates were used for five but no alternate was available for the sixth.

by 1954, all cases had been hired. At that time, only 61% of the employees who ever worked in the plant had been hired, while by 1965, 75% of all employees had been hired for the first time.

In-plant Work History

Of the job codes, only "Operator," was represented by four or more cases (7 gliomas and 2 meningiomas). The Mantel-Haenszel odds ratio for gliomas was 0.54 but, with $X^2_{M-H} = 1.84$, there was no significant difference in proportions, nor any apparent commonality between the departments in which they worked.

When analyzed by department codes, only the maintenance department had four or more cases (8 gliomas and 1 meningioma). The Mantel-Haenszel odds ratio for gliomas was 0.32 with $X^2_{M-H} = 1.37$; the odds ratio does not differ significantly from 1.00. Grouping the accounting codes into major departments yielded no new groups of four or more cases.

When cases and controls were analyzed by potential chemical exposures, a new problem emerged: maintenancemen moved throughout the plant and were exposed to many different agents in an irregular manner. Accordingly, we have examined the data in two ways: in the first, maintenancemen were considered to have been exposed to everything in the plant; in the second, they were excluded from analysis. The first method may be closer to the reality of work in the plant; indeed, maintenancemen may receive higher exposures than operators since in their work they must open pipes, reaction vessels, and pumps.

Table II lists all chemicals to which at least four cases were exposed.

Statistics for distribution of "exposures" among cases and controls are presented in Tables III and IV. The tables include primarily the five chemicals to which four or more cases were exposed and which came closest to showing statistically significant positive association with brain tumors. These chemicals were carbon dioxide, ethylene, styrene, sulfuric acid, and vinyl acetate. Since there was public interest in vinyl chloride monomer at the time the investigation began, it was also included.

Ethylene, like vinyl acetate and vinyl chloride, has an unsaturated two-carbon moiety. Both ethylene and vinyl chloride are metabolized through a highly reactive epoxide stage which may alkylate organic compounds[5,6]. Styrene has been associated with increased sister chromatid exchanges[7], presumably mediated by a reaction oxidizing the ethylene portion of the styrene molecule to form styrene oxide. Thus, although ethylene is not mutagenic in Ames tests (NIOSH, unpublished data) and was not found to have any effect in a two-year exposure study using rats[8], there were biological reasons for considering ethylene, styrene, vinyl acetate, and vinyl chloride further to determine whether any of them might be responsible for the cluster.

Results of analyses by duration of exposure to four chemicals of particular interest (see below) are summarized in Table V. No significant differences in duration of exposure were noted for ethylene, styrene, vinyl acetate, or vinyl chloride monomer.

No significant clustering of areas with proportionately more case years than control-years was detected; study of geographic distribution of cases and controls within the plant offered no useful clues to the etiology of the tumors.

Residential Data

Addresses could be determined for 16 cases. The remaining case was known to have lived for 15 years in Texas City and La Marque, but neither exact dates in each community nor street addresses could be determined. What appear to be complete listings of at least the community of residence were available for 93 of 101 controls; partial listings, often inexplicit as to the exact date of moving from one community to another, were available for another 7 controls. No information at all was available for residence of one control. In most instances, streets or streets and numbers could be determined but there were many instances where informants could no longer remember street addresses of 40 years ago. Table VI shows the distribution of addresses among cases and controls. La Marque, with an apparent excess of cases over controls, lies southwest of Texas City and north of Galveston. The odds ratio for Texas City is significantly lower than one, while that for Galveston is essentially equal to one. The average length of residence in La Marque, excluding those who never lived there, was 12.4 years for cases, while for controls, the average was 16.3 years ($t = -1.54$); the difference is not significant.

To separate the effects of chemical exposures and La Marque residence, we stratified on each variable, treating maintenance workers as exposed. Results are shown in Table VII. The stratified odds ratios for La Marque residence are generally higher than those for exposure to individual chemicals, suggesting that La Marque residence is the more important risk factor.

La Marque is a quiet residential community, without heavy industry, located west of the plant. There is a chemical dump, established in 1959 and listed by the Environmental Protection Agency as one of the high-priority sites for emergency cleanup, at the southeast extremity of La Marque. Vinyl chloride levels as high as 161 parts per billion have been measured at the fence line of the dump[9]. Known addresses for the cases who lived in La Marque appear to cluster toward the southern and western parts of the city, not adjacent to the plant or dump nor downwind from them. Drinking water for La Marque and Texas City comes from deep wells, tapping the same stratum, while water for Galveston comes from the Brazos River.

In order to provide housing for its employees during the period of housing shortage after World War II, the company developed a major subdivision in La Marque. The apparent association between La Marque residence and brain tumors could be related to plant employment if a carcinogenic agent was present in the plant during the late 40's or early 50's and if cases were more likely to live in the development than controls. Since controls began

work an average of a year and a half before their associated cases, they had longer to find and establish permanent residence than the cases; this might explain the different residential patterns observed.

In reviewing the death certificates obtained for case-finding, we found that seven (9.9%) of 71 adult male residents of Galveston County whose death certificates were coded as "malignant brain tumor" and who died between 1949 and 1977 had La Marque addresses on the death certificate. Estimates of La Marque's population over the same period were obtained through the La Marque Library[10]; weighting the populations of the community and county for the calendar years under consideration yields crude death rates of 0.069 adult male deaths per 100,000 total person-years at risk in La Marque and 0.056 for Galveston County (See Table VIII).

Unmatched odds ratios for residence in La Marque by year are shown in Table IX. There was a maximum in the late '50s and early 60's.

Discussion:

Among the in-plant exposures considered, the relationship between brain cancer and carbon dioxide approaches statistical significance only when all work histories are included. We would expect a carcinogen to show stronger relationships when latency was considered; the absence of a latency effect, coupled with the fact that carbon dioxide exposure likely to be experienced

by workers would have virtually no effect on normal physiologic levels, eliminates CO_2 from further consideration. Its appearance on the list serves to illustrate the pitfalls of multiple significance testing mentioned above and to inject a note of caution in forming conclusions based on other associations in this report.

Sulfuric acid did show its strongest association in the period 15 or more years before the death of the case but it is difficult to imagine how workers could absorb significant amounts of sulfuric acid in the environment of this chemical plant. Sulfuric acid is not volatile and is not readily absorbed by the skin; no opportunity for routine exposure to sulfuric acid mist was evident during a walk-through inspection of the plant; significant skin or oral exposure would produce acute symptoms due to its corrosive properties. Alderson and Rattan[11] report two deaths due to brain cancer observed vs. 0.12 expected among workers at an isopropyl alcohol production facility. Isopropanol production there, as at this plant, involved reaction of propylene with sulfuric acid to yield isopropyl sulfate. Conceivably, a reaction product of sulfuric acid with another chemical or group of chemicals could lead to a biologically significant association but this may also be a spurious "significant" association arising from multiple significance testing.

The lack of significant differences between duration of exposure for cases and controls argues against implicating carbon dioxide, ethylene, styrene, sulfuric acid, vinyl acetate, or vinyl chloride monomer as causes of this cluster.

If a time "window" existed for a risk factor at the plant, Figure III suggests that it was open in the late '40s through the early 60's. From Figure II, proportionately more cases than employees in general were first employed between 1941, when hiring for this plant began, and 1953, when all known cases had entered on duty. This is consistent with the findings of the cohort mortality study, which showed that the SMR was higher among those with greater than 15 years duration of employment and latency from the date of first hiring. It is also consistent with the hypothesis of a risk present from the '40s through the early '50's but, since there was relatively little hiring between 1955 and 1965, and there has not been sufficient latency since 1965 to see an effect in the newer workers, we cannot determine whether the risk has diminished.

The observation that risks associated with chemicals are due to covariance with La Marque, Texas residence, rather than visa versa, directs attention to the city. Since La Marque and Texas City share a common water source, but La Marque has a higher ratio of cases to controls than Texas City, a water-borne environmental carcinogen[12] seems unlikely. Since there are no other major chemical or other industries upwind from the community, airborne industrial carcinogens do not seem to be a likely explanation for the association observed. The cases' shorter average duration of residence in La Marque argues against a causal association with residence. From the comparison of crude death rates for La Marque and Galveston County, La Marque does not appear to be over-represented among brain tumor deaths, but this comparison does not assure that a cohort who lived there in the past, some of whom have moved away, is not at greater risk.

Since only one of the eleven cases whose exact addresses in La Marque are known lived in the subdivision developed by the company, it seems unlikely that the association with La Marque residence is a surrogate for an in-plant variable.

Highland Bayou, a slow moving stream draining into Galveston Bay, runs along the southwestern and southern edge of LaMarque and would be upwind from the community. In view of the large number of references associating glioblastomas with viral agents[13-20], a mosquito-born virus seemed an interesting etiological hypothesis, as did kerosene and various insecticides used to control mosquitos during and after World War II. The type of mosquito which constitutes the greatest problem in the area has a range of 25 to 50 miles, so control measures, which relied on DDT and gamma benzene hexachloride until the mid 1960's, have always been county-wide and would not explain localization to this area.[21]

The decline in yearly unmatched odds ratios for La Marque is recent enough that there has not been sufficient latency to see an effect in the newer workers; as with time of hire at the plant, we cannot be certain the risk has diminished.

An initiator-promoter relationship between an occupational factor and either a community environmental factor or an infectious agent is also plausible[22] but without solid support in the data here.

Greenwald[23] has suggested that superior medical care may lead to more frequent diagnoses of brain tumors. Greenwald's article presents evidence of more sophisticated diagnostic methods in Eastman Kodak employees with brain tumors but does not directly assess the question of missed diagnoses in the comparison populations. Schoenburg[24] found that differences between death rates in Rochester, Minn., where the Mayo Clinic provides virtually all medical care, and Connecticut were mainly due to better diagnosis at autopsy, that most of the excess in Minnesota were meningiomas, and that the differences in rates were most pronounced in the older age groups. None of the cases in this series were first diagnosed at autopsy and gliomas predominated in this group (85% vs. 40.3% in Minnesota). We can not determine the extent to which diagnostic sensitivity bias might be a factor in this cluster.

Conclusions:

Exposure to carbon dioxide is almost certainly an example of a spurious "significant" association arising from multiple sampling. Sulfuric acid is also unlikely to be the agent we are seeking, but there is a small possibility that sulfuric acid reacting with some other agent or agents common in the plant could produce a carcinogen. Further work on this possibility would seem justified if sulfuric acid were found associated with brain cancer in other settings. Ethylene and vinyl acetate monomer are better candidates from a biochemical viewpoint but available animal exposure data suggests ethylene is not carcinogenic and when analysis controls for

La Marque residence, the apparent risk diminishes. Associations should be sought in other epidemiologic studies of brain tumors and further animal studies may be appropriate. While the evidence is not conclusive, it suggests that a high risk period existed in the late 40's and early 50's and has since diminished; reexamination of the cohort five and ten years from now might establish this conjecture. The attributable risk associated with La Marque could account for the excess observed although a satisfactory biological explanation is lacking. Inquiry into exposures present in other populations with apparent excesses of brain tumors may provide needed additional clues.

Acknowledgments

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Table I: Cases from Cohort Study Included in and Excluded from Case-Control Study

Diagnosis	Included	Excluded
Gliomas	17	
Glioblastoma multiforme (inc. Astrocytoma III & IV)	14	
Thalamic glioblastoma suspected clinically; no tumor in biopsy of abnormal appearing area of brain cortex	1	
Pituitary adenocarcinoma suspected clinically. Radiotherapy followed by proven glioblastoma 12 years later.	1	
Astrocytoma Grade II	1	
Metastatic tumor, unknown primary		1
Brain tumor suspected clinically, not found at autopsy		1
Meningioma - Malignant		3
- Benign		1
Subtotal	17	6
Total	23	

Table II:
Chemicals to Which Four or More Cases Were Exposed

Acetic acid	Isopropanol	Sodium carbonate
Acetone	Isopropyl acetate	Sodium hydroxide
Carbon dioxide	Isopropyl peroxydicarbonate	Sodium sulfate
Diethanolamine	Lube oils	Styrene
Diethyl sulfate	Methane	Sulfuric acid
Ethylene	Methanol	Toluene
Ethylene glycol	Methyl ethyl ketone	Vinyl acetate
Hydrochloric acid	Methyl isobutyl ketone	Vinyl chloride
	Nonane	

Table III: Statistics for Distribution Among Cases and Controls of Workers Exposed to Selected Chemicals (Maintenancemen Counted as Exposed; UNK = Unexposed)

Chemical	Cases Latency*	Cases Expos/Unexp	$X_{(M-H)}$	$R_{(M-H)}$	$\underline{R}/\overline{R}$
1. Carbon Dioxide	15+	12/3	0.65	1.60	0.49/ 5.21
	ever	15/2	1.74	3.52	1.07/ 11.60
2. Ethylene	15+	13/2	0.63	1.63	0.45/ 5.92
	ever	14/3	0.51	1.39	0.48/ 4.08
3. Styrene	15+	8/7	-0.60	0.74	0.32/ 1.69
	ever	11/6	0.41	1.22	0.55/ 2.67
4. Sulfuric Acid	15+	12/3	0.38	1.33	0.39/ 4.56
	ever	14/3	0.87	1.77	0.60/ 5.20
5. Vinyl Acetate	15+	11/4	1.03	1.97	0.67/ 5.84
	ever	13/4	1.52	2.55	0.22/ 29.69
6. Vinyl Chloride	15+	8/7	-0.26	0.88	0.37/ 2.08
	ever	11/6	0.41	1.22	0.55/ 2.67

* 15+ = work 15 or more years before death of case.

$X_{(M-H)}$ = Mantel-Haenszel Chi; $R_{(M-H)}$ = Odds ratio estimate;

$\underline{R}/\overline{R}$ = lower and upper limits of 90% confidence interval on $R_{(M-H)}$

Table IV: Statistics for Distribution Among Cases and Controls of Workers Exposed to Selected Chemicals (Maintenancemen Excluded; Workers with Maintenance plus Other Departments without Exposure Counted as Unexposed; UNK = Unexposed)

Chemical	Cases Latency*	Cases Expos/Unexp	$X_{(M-H)}$	$R_{(M-H)}$	$\underline{R}/\overline{R}$
1. Carbon Dioxide	15+	5/4	0.51	1.54	0.38/ 6.23
	ever	7/4	1.30	2.38	0.79/ 7.10
2. Ethylene	15+	7/2	1.41	3.09	0.82/ 11.62
	ever	7/4	0.51	1.41	0.49/ 4.08
3. Styrene	15+	2/7	-0.72	0.58	0.17/ 2.02
	ever	4/7	0.30	1.22	0.41/ 3.62
4. Sulfuric Acid	15+	6/3	1.72	6.13	1.08/ 34.67
	ever	6/5	0.83	1.76	0.58/ 5.34
5. Vinyl Acetate	15+	5/4	1.15	2.98	0.62/ 14.38
	ever	6/5	1.36	3.13	0.78/ 12.56
6. Vinyl Chloride	15+	2/7	-0.15	0.88	0.20/ 3.76
	ever	4/7	0.27	1.22	0.36/ 4.21

* 15+ = work 15 or more years before death of case.

$X_{(M-H)}$ = Mantel-Haenszel Chi; $R_{(M-H)}$ = Odds ratio estimate;

$\underline{R}/\overline{R}$ = lower and upper limits of 90% confidence interval on $R_{(M-H)}$

Table V: Comparison of Cases and Controls
By Years of Exposure to Selected Chemicals
(15 years or more before death of case.
Employees with no exposure excluded.)

Unmatched Analysis

	Time in Maintenance Dept. excluded.		Maintenance Dept. Time Counted as Exposed	
	Cases	Controls	Cases	Controls
	N Mean ± SE	N Mean ± SE	N Mean ± SE	N Mean ± SE
Ethylene	7 63.3±69.3 SE = 26.2	13 64.5±67.6 SE = 18.8	13 82.0±65.5 SE = 18.2	78 76.3±53.2 SE = 6.02
Styrene	2 35.0±39.6 SE = 28.0	15 52.7±59.7 SE = 15.4	9 100.7±94.5 SE = 31.5	57 75.4±60.6 SE = 8.02
Vinyl Acetate	5 62.2±52.6 SE = 23.6	15 73.4±56.7 SE = 14.6	11 84.9±58.2 SE = 17.6	58 81.6±57.3 SE = 7.52
Vinyl Chloride	3 73.7±70.6 SE = 40.8	15 71.9±66.1 SE = 17.1	57 84.6±62.0 SE = 8.21	10 105.7±90.6 SE = 28.7

SD = Standard deviation; SE = Standard error of the mean.

Table VI: Distribution Among Cases and Controls of Community of Residence

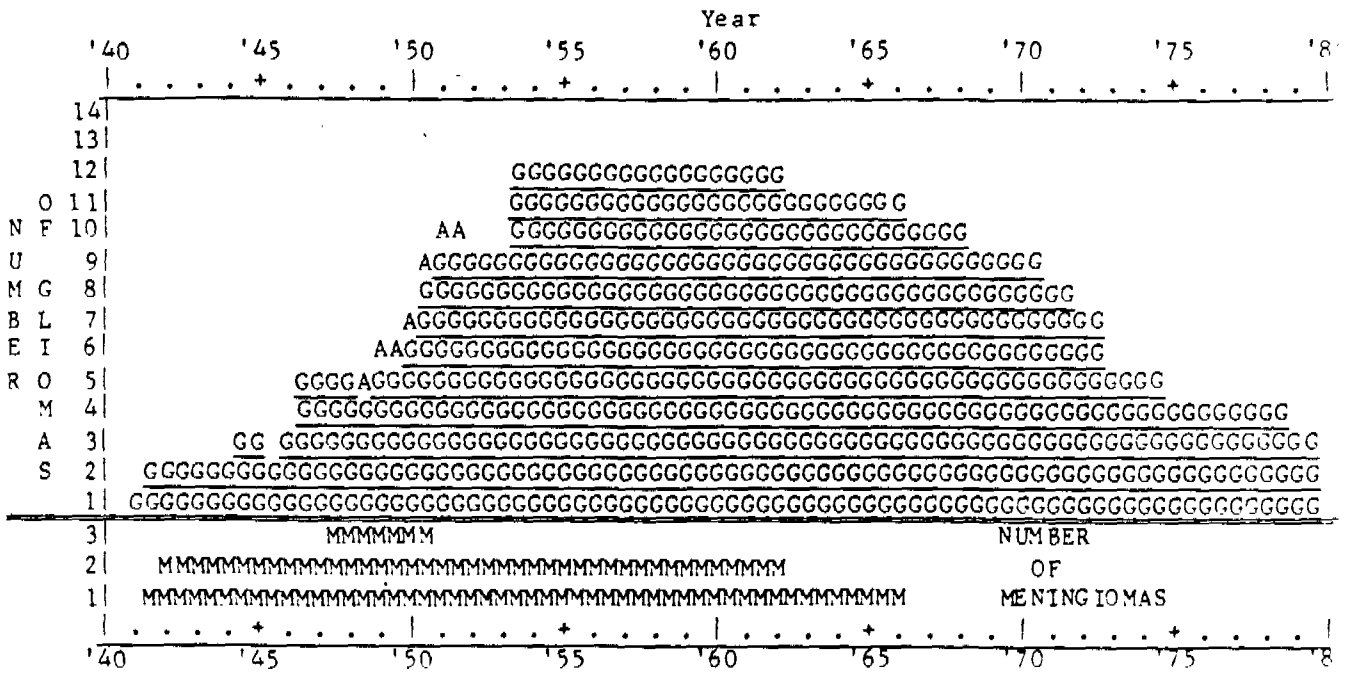
Community	Latency*	Cases Lived Ever/Never	$X_{(M-H)}$	$R_{(M-H)}$	$\underline{R}/\overline{R}$
1. LaMarque	15+	9/8	2.37	4.80	1.61/ 14.26
	0-14	9/8	2.50	3.95	1.60/ 9.77
	ever	12/5	3.04	5.86	2.25/ 15.25
2. Texas City	15+	4/13	-1.87	0.28	0.09/ 0.86
	0-14	5/12	-1.12	0.48	0.16/ 1.41
	ever	6/11	-1.21	0.49	0.19/ 1.29
3. Galveston	15+	7/10	-0.28	0.87	0.36/ 2.06
	0-14	3/14	-0.13	0.92	0.32/ 2.67
	ever	7/10	-0.35	0.83	0.36/ 1.96

* 15+ = work 15 or more years before death of case.

$X_{(M-H)}$ = Mantel-Haenszel Chi; $R_{(M-H)}$ = Odds ratio estimate;

$\underline{R}/\overline{R}$ = lower and upper limits of 90% confidence interval on $R_{(M-H)}$

Figure 1: Number of Cases Employed During Each Year 1940 - 1980



G = Glioblastoma, including Astrocytoma Grade III or IV;
A = Astrocytoma Grade II; M = Malignant Meningiomas

Table VII: Unmatched Odds Ratios for Exposure to Selected Substances Stratified by La Marque Residence and for La Marque Residence Stratified by Exposure

Substance / Time Periods	Odds Ratios for: Substance Exposure LaM		La Marque Residence Sub.	Sub.
CO_2				
15+ yrs.	1.88	0.73	5.14	3.95
0-14 yrs.	-.--	3.43	-.--	2.79
Ever	2.49	4.50	1.16	4.42
Ethylene				
15+ yrs.	-.--	1.60	-.--	3.47
0-14 yrs.	-.--	1.33	-.--	2.17
Ever	-.--	2.05	-.--	3.39
Styrene				
15+ yrs.	0.35	1.17	2.25	7.58
0-14 yrs.	3.24	0.76	8.25	1.94
Ever	0.94	0.98	3.88	4.05
Sulfuric Acid				
15+ yrs.	1.35	1.16	7.14	3.85
0-14 yrs.	-.--	0.40	-.--	1.85
Ever	-.--	2.00	-.--	2.86
Vinyl Acetate				
15+ yrs.	0.69	3.29	1.29	6.12
0-14 yrs.	2.57	3.43	2.38	3.17
Ever	0.99	4.50	1.19	5.38
Vinyl Chloride				
15+ yrs.	0.37	1.17	2.33	7.39
0-14 yrs.	2.37	0.62	7.71	2.03
Ever	0.94	0.82	4.43	3.85

$\overline{\text{LaM}}$ = Did not live in La Marque during period. LaM = Lived in La Marque during period. $\overline{\text{Sub.}}$ = Was not exposed to substance during period. Sub. = Was exposed to substance during period.

Table VIII: Population and brain tumor cases from LaMarque and Galveston County, Texas by time

	1949 - 1954	1955 - 1964	1965 - 1974	1975 - 1977	Total
Population:					(Time-weighted)
La Marque[1]	7,359	13,969	16,131	15,372	349,870
Galv. County[2]	112,226	140,364	169,812	195,940	4,362,936
(Percent)	(6.56)	(9.95)	(9.50)	(7.85)	(8.02)
Cases:[3]					
La Marque	0	2	5	0	7
Galv. County	3	19	30	19	71
(Percent)	(0.00)	(10.53)	(16.67)	(0.00)	(9.86)

1 City of La Marque, Texas, Comprehensive Planning Program. (ref.13)

2 United States Decennial Census

3 Data derived from case-finding step and includes only males, over 20 years of age, resident in Galveston County at the time of death, who died in Texas and whose death certificate was coded by Texas nosologists as "Malignant Brain Tumor".

Table IX: Unmatched Odds Ratios
Associated with La Marque Residence by Calendar Year

	GLIOMAS			CONTROLS			Odds Ratio
	LaM	LaM	TOT	LaM	LaM	TOT	
1940	1	9	10	1	58	59	6.44
1	1	9	10	2	57	59	3.17
2	0	10	10	3	56	59	0.00
3	1	9	10	4	55	59	1.53
4	1	9	10	3	56	59	2.07
5	1	10	11	4	61	65	1.53
6	1	11	12	3	68	71	2.06
7	1	11	12	3	68	71	2.06
8	1	12	13	9	68	77	0.63
9	2	14	16	12	83	95	0.99
1950	4	12	16	14	81	95	1.93
1	5	12	17	15	86	101	2.39
2	7	10	17	16	84	101	3.46
3	7	10	17	19	82	101	3.02
4	7	10	17	20	81	101	2.84
5	6	11	17	21	80	101	2.08
6	6	10	16	22	73	95	1.99
7	7	9	16	21	75	96	2.78
8	9	7	16	20	76	96	4.89
9	9	7	16	20	76	96	4.89
1960	9	7	16	19	77	96	5.21
1	8	8	16	19	77	96	4.05
2	7	9	16	19	77	96	3.15
3	7	8	15	18	72	90	3.50
4	7	8	15	17	73	90	3.76
5	5	8	13	17	61	78	2.24
6	5	7	12	16	56	72	2.50
7	6	6	12	16	56	72	3.50
8	6	5	11	16	50	66	3.75
9	5	6	11	14	52	66	3.10
1970	4	7	11	14	52	66	2.12
1	4	6	10	14	46	60	1.88
2	3	5	8	12	36	48	1.80
3	3	5	8	12	36	48	1.80
4	3	4	7	10	32	42	2.40
5	2	3	5	8	22	30	1.83
6	2	2	4	7	17	24	2.43
7	2	1	3	7	11	18	3.14
8	2	1	3	7	11	18	3.14
9	2	1	3	6	12	18	4.00
1980	1	0	1	2	4	6	-.--

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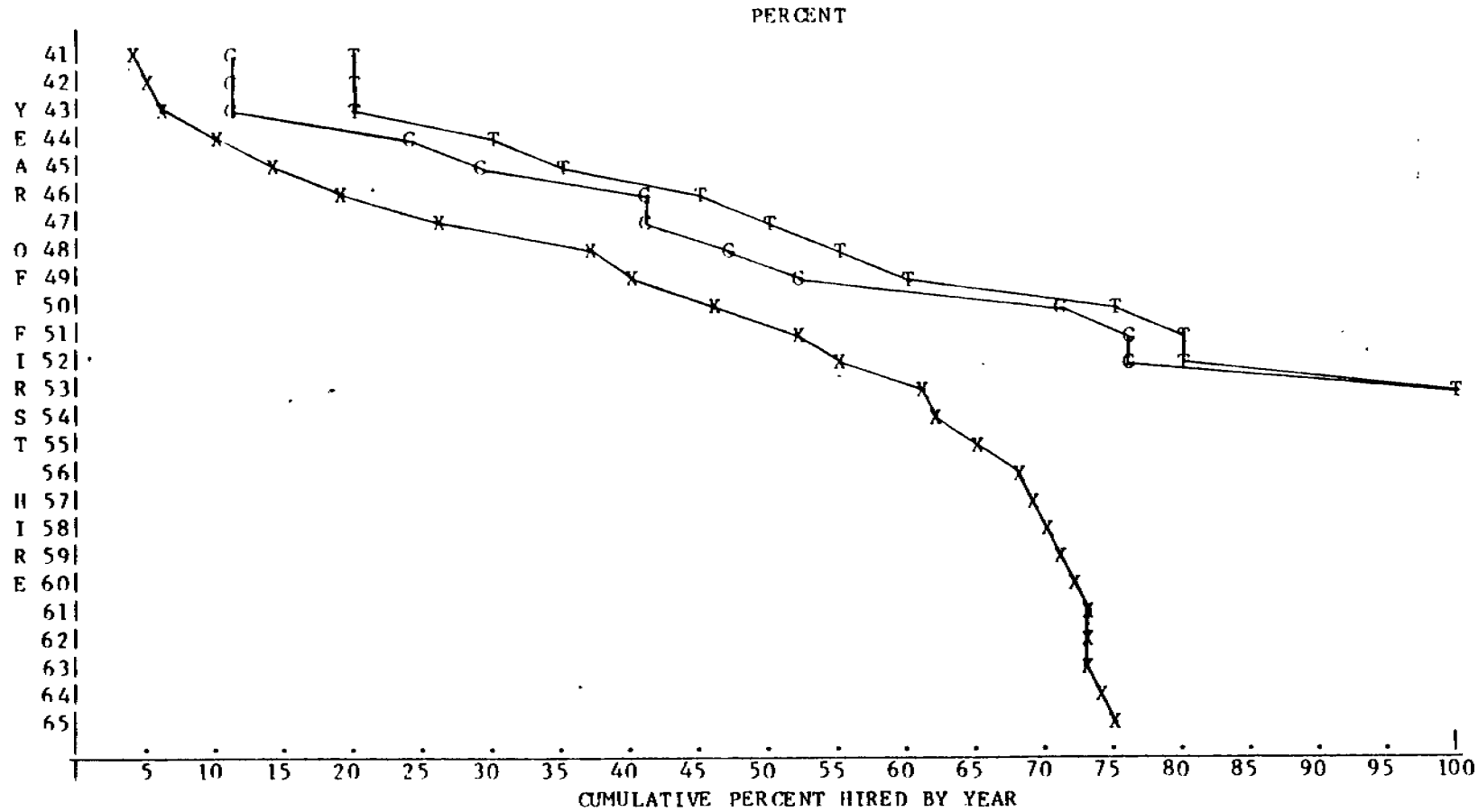
Figure II: Cumulative Percent of All Workers, Gliomas, and All Cases Hired by Year: 1941 - 1965
(Denominators = All in Class for All Years)



X = All Workers; G = Gliomas; T = Total of All Cases (Gliomas + Meningiomas)