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HETA 92-0232-2767
Grady Memorial Hospital
Atlanta, Georgia

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PREFACE

The Hazard Evaluations and Technical Assistance Branch (HETAB) of the National Institute for Occupational Safety and Health (NIOSH) conducts field investigations of possible health hazards in the workplace. These investigations are conducted under the authority of Section 20(a)(6) of the Occupational Safety and Health Act of 1970, 29 U.S.C. 669(a)(6) which authorizes the Secretary of Health and Human Services, following a written request from any employer or authorized representative of employees, to determine whether any substance normally found in the place of employment has potentially toxic effects in such concentrations as used or found.

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ACKNOWLEDGMENTS AND AVAILABILITY OF REPORT

This report was prepared by Aubrey Miller and Allison Tepper of HETAB, Division of Surveillance, Hazard Evaluations and Field Studies. Karl Sieber provided statistical consultation and performed data analysis. John Decker conducted the industrial hygiene evaluation. Patricia Laber provided computer programming support. Jenise Brassell, BJ Haussler, Kim Jenkins, and Pat McGraw microfilmed medical and personnel records, and BJ Haussler managed and edited these data. Max Kiefer, Stanley Salisbury, and Christine Hudson provided industrial hygiene field assistance. Desktop publishing was performed by Patricia McGraw. Review and preparation for printing were performed by Penny Arthur.

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Health Hazard Evaluation Report 92-0232-2767
Grady Memorial Hospital
Atlanta, Georgia
November 1999

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SUMMARY

On April 16, 1992, the National Institute for Occupational Safety and Health (NIOSH) received a request from the American Federation of State, County, and Municipal Employees (AFSCME) for a Health Hazard Evaluation (HHE) at Grady Memorial Hospital (GMH) in Atlanta, Georgia. The request concerned the risk of transmission of *Mycobacterium tuberculosis* (MTB) to hospital workers. Additionally, the hospital requested NIOSH assistance in evaluating aerosol control and containment efforts (i.e., fan systems in patient rooms, new isolation rooms) to reduce the potential for nosocomial MTB infection. In response to these requests, NIOSH investigators conducted numerous site visits to GMH throughout the fall and winter of 1992, and spring of 1993. Information from the evaluation of the hospital environment is described in letters sent to hospital management and union representatives. These letters are included as Appendices to this report. The remainder of this report focuses on the epidemiologic study of the risk of MTB transmission (as defined by tuberculin skin test [TST] conversions) among hospital workers with "patient contact" compared to workers with "no patient contact." This information was described in a letter that was sent to the hospital and union in February 1998.

A retrospective cohort study of hospital workers employed at GMH from January 1, 1990, through September 30, 1992, was performed. Personal, community, and occupational risk factors for TST conversion were evaluated in 2,362 workers with potential tuberculosis exposure and 886 workers with little or no potential for exposure. The rate of TST conversion was 5.8% for workers with potential exposure and 2.0% for workers with little or no exposure. The adjusted relative risk (RR) was 3.6 (95% confidence interval [CI] 2.2, 5.8). Among workers with potential exposure, statistically significantly elevated risks were found for nurses (RR 6.5; 95% CI 3.2, 13.1), laboratory technicians (RR 5.8; 95% CI 2.2,15.1), pharmacy workers (RR 5.2; 95% CI 1.9, 14.5), phlebotomists (RR 5.2; 95% CI 1.1, 25.1), emergency room workers (RR 4.6; 95% CI 2.0, 10.9), housekeepers (RR 4.4; 95% CI 1.9, 10.0), clerks (RR 4.3; 95% CI 1.6, 11.9), and emergency responders (RR 2.8; 95% CI 1.1, 6.7). Among nurses, the risk was related to a proxy measure of occupational TB exposure (i.e., the number of positive MTB cultures from their work location). The adjusted relative risks were 12.6 (95% CI 5.4, 29.6), 6.0 (95% CI 2.5, 14.6), and 2.9 (95% CI 0.9, 10.0) for nurses in the "high," "medium," and "low" exposure wards, respectively. The risks for clerks was less clearly related to exposure; the adjusted relative risks were 7.9 (95% CI 1.6, 38.8), 12.2 (95% CI 2.5, 59.8), and 1.9 (95% CI 0.2, 15.1) for clerks in the "high," "medium," and "low" exposure wards, respectively.

Workers with patient contact and those employed in certain occupational groups were at increased risk for occupational MTB infection. Since the NIOSH evaluation, the hospital has undergone many renovations and has implemented new TB control measures including additional negative-pressure rooms, expanded respiratory isolation of patients known or suspected to have TB, expanded employee education about TB, and issuance of submicron masks for workers entering respiratory isolation areas. Data analyzed by GMH staff show a subsequent reduction in TST conversions among hospital employees.

KEYWORDS: SIC 8062 (General medical and surgical hospitals), tuberculosis, hospital workers, occupational exposure, nosocomial transmission, tuberculin skin test.

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INTRODUCTION

On April 16, 1992, the National Institute for Occupational Safety and Health (NIOSH) received a request from the American Federation of State, County, and Municipal Employees (AFSCME) for a Health Hazard Evaluation (HHE) at Grady Memorial Hospital (GMH) in Atlanta, Georgia. The request concerned the risk of transmission of *Mycobacterium tuberculosis* (MTB) to hospital workers. Additionally, the hospital requested NIOSH assistance in evaluating aerosol control and containment efforts (i.e., fan systems in patient rooms, new isolation rooms) to reduce the potential for nosocomial MTB infection. In response to these requests, NIOSH investigators conducted numerous site visits to GMH throughout the fall and winter of 1992, and spring of 1993. Information from the evaluation of the hospital environment is described in letters and reports sent to hospital management and union representatives in June 1992, January 1994, and August 1994. These letters and reports are included as Appendices to this report. Additionally, a letter describing interim results of the epidemiologic study was sent in February 1998. The remainder of this report focuses on the epidemiologic study of the risk of tuberculosis transmission (as defined by tuberculin skin test (TST) conversions) among hospital workers with "patient contact" compared to workers with "no patient contact." This information was described in a letter that was sent to the hospital and union in February 1998.

BACKGROUND

GMH is a public, university affiliated, 1,000-bed inner-city hospital in Atlanta, Georgia. The hospital employs about 5,000 workers in professional, technical, and support positions. Nearly 50,000 patients are admitted and over 850,000 clinic visits are made to the hospital each year. Over the few years prior to and during the study period, the hospital annually cared for more than 200 patients with laboratory-confirmed TB.

Prior to July 1992, hospital policy required that all employees (except physicians) have annual one-step TSTs placed and read by trained employee staff. Also prior to July 1992, students and hospital volunteers were not included in the TST program. Reportedly, employee compliance with the hospital TST program has been very good since about 1976, when a policy was instituted requiring verification of an adequate TST for annual renewal of hospital identification cards. Since July 1992, all employees have been required to have TSTs every six months.

According to hospital policy (from at least 1976 through September 30, 1992, a positive TST was defined as a reaction at 48-72 hours of at least 10 millimeter to a Mantoux skin test using 5 tuberculin units of purified protein derivative (PPD). A positive TST in a person who had a previous recorded negative TST was considered a TST conversion. Skin test results for all workers with a positive TST were recorded; workers with positive results were immediately referred for further evaluation and follow-up. No negative results were assumed; TST results had to be read and documented by employee health staff in order to be recorded as "negative." However, skin reaction sizes of negative tests (< 10 mm) were not typically recorded on the health records. Workers judged by employee health staff to have an accurate history of a past positive TST were not given subsequent TSTs. The hospital excluded workers from their annual TST program if they had a documented or clear history of a previously positive TST or diagnosis of TB. No exclusions were made based solely on a history of BCG vaccination.

According to hospital management, the number of patients with TB had not changed significantly over the few years preceding the HHE request. During annual TST screening by GMH Employee Health Services in January 1992, there appeared to be an increased number of skin test conversions among health care workers on Wards 7B and 10B. In response, on February 28, 1992, GMH formed a TB Task Force to review procedures and the physical facility. In March and April 1992, GMH Employee Health Services offered TSTs to all hospital employees, emphasizing the importance of testing in those employees working in identified high risk areas. In April 1992, hospital management asked the Centers for Disease Control (CDC) to investigate a possible TB outbreak among employees in Wards 7B and 10B. The CDC investigation was conducted by the National Center for Infectious Diseases, Hospital Infections Program (NCID/HIP) in collaboration with this NIOSH HHE.[1]

METHODS

Study Group

Employees listed in the employee payroll database who had actively worked for at least one quarter between January 1, 1990, and September 30, 1992, (the study period) were eligible for the study. This study period was chosen because of the availability of computerized employee payroll records on a quarterly basis.

Data Collection and Definition of Variables

Demographic and Work History Data

Data extracted from the employee payroll database included name, social security number, date of birth, date of hire, race/ethnicity, gender, home zip code, salary, job title, and pay station (indicates the specific geographic location of work or department of employment) for each quarter the employee worked at GMH during the study period. For purposes of analysis, age was defined as the worker's age at the midpoint of the study period (May 1, 1991) and salary was defined as the worker's average hourly salary over the study period. For the multivariate analysis, time employed in an occupational classification was calculated as the difference (in days) between date of hire (or, if hired before the beginning of the study, January 1, 1990) and a termination date assigned based on the last quarter for which payroll records were available. For descriptive analysis, duration of employment (in years) was calculated based on date of hire and number of quarters the worker was an active employee at GMH. If missing, dates of termination were assigned using a random-date generator that selected a date between the last known payroll date and start of the next payroll quarter.

Eligible workers were grouped into "patient contact" and "no patient contact" cohorts by evaluation of their geographic location of work and the type of work they performed. Groups selected for each cohort were reviewed with the hospital staff to help insure accuracy of the exposure classifications. The "patient contact" cohort consisted of (1) workers with direct patient contact who were employed at stationary work locations anywhere within the hospital (e.g., in-patient ward nurses and clerks, emergency room workers); (2) workers in selected occupations that require direct contact with patients from different areas of the hospital (e.g., respiratory therapists, transporters, housekeepers, radiology technicians, and phlebotomists); and (3) workers who may have contact with potentially infectious patient specimens (e.g., laboratory workers). The "no patient contact" cohort consisted of workers employed at stationary work locations or occupations/positions which did not require any direct patient contact (e.g., administrative office workers, medical records clerks, laundry workers, and financial affairs staff).

Additionally, nurses and clerks (within the "patient contact" cohort) employed exclusively on in-patient wards were classified as "high," "medium," and "low" potential TB exposure based on the number of positive pulmonary TB cultures submitted from each in-patient ward from January 89 through May 92. At the time of this study, 31 hospital wards housed patients; 17 were primarily adult medical and surgical wards. The remaining 14 in-patient wards consisted of 1 psychiatry ward, 1 burn ward, 3 pediatric wards, 1 gynecology ward, and 8 obstetrics/neonatal wards. Of the 640 positive pulmonary TB cultures submitted, 628 (98.1%) were sent from the 17 adult medical and surgical in-patient wards, whereas only 12 (0.9%) of the cultures were sent from the other 14 wards. Eight adult medical/surgical wards, each of which had 30 or more positive cultures, comprised the "high" exposure group. The "medium" exposure group consisted of 9 adult medical/surgical wards, each of which had 10-29 positive cultures. The "low" exposure group consisted of the remaining 14 wards (non-medical/surgical), each of which had less than 10 positive cultures. The distribution of positive pulmonary TB cultures from in-patient wards showed little variation over the time period January 89 - May 92. A random review of areas of hospitalization for 150 patients with positive pulmonary TB cultures found that while approximately 25% of the patients changed wards during their hospitalization, none were hospitalized on both medical/surgical wards and non-medical/surgical wards during their stay.

Population-based demographic data were evaluated by using each employee's most frequent zip code of residence during the study period. The information was extracted from the 1990 U.S. Census of Population and Housing,[2] and was included to evaluate sociodemographic factors potentially related to the risk of TST conversion. The three-year incidence rate of TB was determined for each employee's zip code of residence by dividing the number of incident TB cases for 1990-1992 for each zip code[3] by its 1990 population.

TST Data

Health records of all eligible employees were reviewed to determine TST status, date of first positive TST (if conversion occurred after beginning work at GMH), frequency of TSTs, and history of BCG vaccination. Workers (including those who received the BCG vaccine) were included in this study if they had at least two TSTs during the study period and tested negative on the first test.

A TST convertor was defined as a person who had a documented positive TST result (any reaction of 10 mm or greater) and a documented previous negative result during the study period. This definition of a TST conversion was based on the available data from the hospital TST program and differs from the current CDC guidelines, which recommend that only specific increases in induration (the magnitude of which depends on a variety of risk factors) be considered evidence of a true TST conversion.[4] Since conversion could have occurred any time between the positive and prior negative TST, a random date between the negative and positive result dates was assigned using a computerized random-date generator with all dates during the period having an equal probability of selection. To address the possibility of a "booster" phenomenon[5] and any uncertainties associated with BCG vaccination histories, we did an additional analysis using only workers with two or more documented negative TSTs prior to conversion.

Data Analysis

TST Conversion

Unadjusted rates of conversion were determined for workers **always** employed in the "no patient contact" group, "patient contact" group, and the specific occupations and work areas for the entire study period and separately by year. Unadjusted conversion rates for each group of interest were calculated by dividing the number of new TST conversions by the number of workers at risk to convert.

To assess the risk of TST conversion by controlling for potential confounders, a proportional hazards (P-H) regression model was used.[6] The assumption of proportionality for this model was tested and met. The measure of risk determined from a P-H regression model is the relative risk (RR), that is, the rate in the exposed group compared to the rate in the unexposed group. When the RR is greater than 1, the risk is thought to be increased. A 95% confidence interval (CI) around the RR was also calculated. When the CI excludes 1, an increased risk is said to be statistically significant.

Risk factors for TST conversion were evaluated in a series of univariate analyses with outbreak wards (7B and 10B) both included and excluded. Variables considered were exposure group ("patient contact," "no patient contact"), employee age (age at midpoint of study in 10-year intervals), duration of employment (years employed as of last quarter or termination, as quartiles), race (white, nonwhite), gender, hourly wage (average over study period, as quartiles), and several measures of community TB exposure and socioeconomic status for the employee's zip code of residence, including 3-year TB incidence rate, TST conversion rate among employees residing in a given zip code, average household size, per capita income, unemployment rate, and percentage of incomes below the poverty level. Risk factors with p<0.2 in the univariate analysis were considered for inclusion in a multivariate P-H model. All variables except per capita income, average household size, and unemployment rate were statistically significant at p<0.2 in the univariate analysis.

A stepwise procedure was used to determine risk factors to include in the final P-H multivariate model. Risk factors found to be statistically significant in univariate analyses were fit, and individual risk factors were added or removed until the fit of the model showed no statistically significant change at p<0.05. All adjusted RR of TST conversion subsequently presented are based on this final P-H model, which included variables for exposure group, employee age (RR 1.2; 95% CI 1.0, 1.5), race (RR 1.9; 95% CI 1.2, 3.0), 3-year TB incidence rate in employee's zip code of residence (RR 1.0; 95% CI 1.0, 1.1), gender (RR 0.6; 95% CI 0.4, 0.8), and duration of employment (RR 0.6; 95% CI 0.5, 0.7).

Prevalence of TST Positive

Unadjusted prevalence rates (i.e., the number of workers who were TST positive at the beginning of the study or upon first TST during the study divided by the number of workers with adequate health and personnel records) were determined for workers always in the same occupational group for the entire study period.

Attributable Risk

The population attributable fraction of TST conversion in this study (also called etiologic fraction or the attributable risk) is the excess TST conversion associated with patient contact in the study population or occupational group of interest. The population attributable risk was calculated using the following formula.[7]

$$\frac{\text{Prevalence of patient contact in the population or occupational group) (Relative Risk - 1)}}{1 + [\text{(Prevalence of patient contact in the population or occupational group) (Relative Risk - 1)}]}$$

The unadjusted RR was used, based on the ratio of TST conversion rate in the group of interest and that among unexposed workers in the population.

RESULTS

Study Group

The total number of employees during the study period was 10,545. Of this group, 4,829 workers were excluded from further analysis because they: (1) worked in offsite hospital facilities/clinics (157) or in other hospital areas for which exposure could not be classified (483);(2) were physicians, students, or volunteers, or members of other groups that were not included in the TST program (1,383); (3) were actively employed at the hospital for less than 1 quarter during the study period (2,071); (4) had multiple personnel records containing inconsistent data (39), or (5) had missing or incomplete TST records (696).

Of the 5,716 employees with adequate health and personnel records, 2,412 (42%) were excluded from analysis of conversion rates because they were not eligible to convert their TST during the study: 1,173 were TST positive at entry or upon first testing in the study period, 1,224 had fewer than two TSTs during the study period, and 15 had less than 30 days between their first and last TST. Of the remaining 3,304 employees eligible to convert their TST during the study period, 27% (886) of the workers were classified as having no known patient contact ("no patient contact" cohort); and 73% (2,418) were classified as having some contact with patients or patient laboratory specimens ("patient contact" cohort). An outbreak of TB occurred among nurses and clerks employed on two in-patient wards between July 1991 and March 1992. Fifty-six workers (47 nurses and 9 clerks) were employed in these two hospital wards during the study period. Unless otherwise noted, these workers were excluded from the analyses presented below.

Demographic Characteristics

The distributions of demographic characteristics of workers by exposure group and TST converter status are presented in Table 1. Analysis of the demographic characteristics of the "no patient contact" and "patient contact" groups revealed relatively small differences in age, hourly wage, and duration of employment. More notable differences were found for sex and race, with the patient contact group having a larger percentage of female workers and smaller percentage of nonwhite workers. The racial distribution for the entire study group was 23.5% white, 74% black, and 2.5% other (Asian, American Indian, Latin American, and unspecified). As a group, converters had a lower percentage of females, higher percentage of nonwhites, shorter duration of employment, and lower wages than nonconverters. The distributions of demographic characteristics of workers who were TST positive upon entry to the study and thus excluded from the analysis of conversion, but included in the analysis of prevalence, are also shown in Table 1. This group was older, had a higher percentage of nonwhites, and was employed longer compared to the study group. Of note, only 1.1% of the entire study group had a history of BCG vaccination recorded in their health records: 4.7% of those TST positive at entry, 1.1% of TST converters, 0.2% of the "patient contact" group, and none of the "no patient contact" group.

TST Conversion

Risk of Conversion

The crude TST conversion rates by demographic characteristics are shown in Table 2. Statistically significant increased rates of TST conversion were associated with male gender and non-white race ($p<0.05$). Also, statistically significant trends of increasing TST conversion were associated with decreasing hourly wage and duration of employment ($p<0.05$). There was no statistically significant association of TST conversion with age.

Table 3 shows that the rate of TST conversion was 5.8% (138/2362) in the "patient contact" group, compared to 2.0% (18/886) in the "no patient contact" group. The unadjusted RR (not shown in Table 3) was 2.9 (95% CI 1.8, 4.7). The RR after adjustment for age, race, gender, duration of employment, and TB incidence rate in the employee's zip code of residence was 3.6 (95% CI 2.2, 5.8).

While most workers (85%) stayed in the same job over the study period, there was some movement between jobs, which varied among different occupational groups. The following analyses were limited to those workers who always stayed within the same occupational category throughout the entire study period.

The TST conversion rate for all nurses with patient contact was 5.5% (29/525), with an adjusted RR of 6.5 (95% CI 3.2, 13.1). Among in-patient ward nurses, a statistically significant trend (chi-square for linear trend, $p<0.01$) was observed with TST conversion rate and the number of positive TB cultures from the in-patient wards on which the nurses worked. Conversions occurred in 12.5% of the nurses in the "high" exposure wards, 9% of the nurses in the "medium" exposure wards, and 1.8% of the nurses in the "low" exposure wards. The adjusted RR were 12.6, 6.0, and 2.9, respectively. For the "high"- and "medium"-exposure wards, the RRs were statistically significantly elevated (compared to the "low"-exposure wards).

The TST conversion rate for all clerks with patient contact was 6.1% (7/114), with an adjusted RR of 4.3 (95% CI 1.6, 11.9). Among in-patient ward clerks, those who worked on "high"-and "medium"-exposure wards had similar rates of conversion, 13.6% and 12.5%, respectively. The RR for these areas were 7.9 and 12.2, respectively, and were statistically significantly elevated. Only two percent of clerks in the "low"-exposure wards converted; the increased RR (1.9) was not statistically significant.

Evaluation of other occupations and work areas revealed statistically significantly elevated adjusted RR for lab workers (5.8), pharmacy workers (5.2), phlebotomists (5.2), housekeepers (4.4), emergency room workers (4.6), and emergency responders (2.8), such as emergency medical technicians and paramedics. For some occupations (clerks, food service workers, laboratory workers, pharmacy workers) we were able to compare the rate of TST conversions among workers with "patient contact" to those in the same occupation with "no patient contact" (data not shown). The rate of TST conversions among clerks with "patient contact" was 6.1% (7/114), over three times higher than among clerks with "no patient contact," 1.8% (6/329). Food service workers with "patient contact" had a 6.9% (3/49) rate of TST conversion compared to a rate of 1.5% (1/69) for food service workers with "no patient contact." Also, pharmacy workers with "patient contact" had a TST conversion rate of 10.4% (5/48), which was notably higher than pharmacy workers with "no patient contact" (none of 15). Among lab workers who may routinely handle specimens containing MTB (i.e., pathology, cytology, bacteriology, urinalysis, autopsy labs), the TST conversion rate was 14.3% (3/21), about 2-fold higher than lab workers who are not known to routinely handle specimens containing MTB (i.e., hematology, blood bank, chemistry, radioassay, serology) 7.5% (3/40).

To examine the annual variation of TST conversions and the potential effect throughout the hospital of the nosocomial TB outbreak in two in-patient wards, the rates and risks of TST conversion by year (1990, 1991, January 1 - September 30, 1992) were evaluated. While the conversion rates varied from year to year for both exposure groups, the rate of conversions for the "patient contact" group remained approximately two-to-three-fold higher than for the "no patient contact" group for each of the study years. The respective conversion rates among the "patient contact" group for 1990,1991, and January 1 - September 30, 1992, were 1.1%, 2.3%, and 1.9%, as compared to 0.6%, 0.9%, and 0.6% for the "no patient contact" group. Rates for specific occupations with "patient contact" that had significantly elevated risks of TST conversion also varied from year to year. Aside from nurses in the medium wards (highest in 1990) and emergency responders (highest in 1992), the rates for all other groups were highest during 1991, the year prior to the outbreak on Wards 7B and 10B.

Booster Phenomenon

To address the possibility that workers had a false negative TST prior to "conversion," and that the apparent conversion represented a "booster" phenomenon rather than a true conversion, we repeated our analyses using **only** workers with **2 or more documented negative TSTs prior to conversion**. This approach had variable effects on our point estimates of the risk of conversion for several of the exposure groups, but did not affect the overall findings. Except for phlebotomists, the elevated risks identified in the previous analyses remained elevated (Table 4).

Size of Test Reaction Among Converters

The hospital's definition of a TST conversion (any reaction of 10 mm or greater) differed from current CDC guidelines, which recommend that only specific **increases** in induration (the magnitude of which depends on a variety of risk factors) be considered evidence of a newly-acquired infection with TB.[4] Thus, an analysis was performed to determine if the risk of having a TST 20 mm or larger (which would eliminate the TST "conversions" of less than 10 mm) was significantly greater in the "patient contact" group than in the "no patient contact" group. Among 156 converters whose reaction size was known (only 10 were unknown), the TST reaction size was 20 mm or larger for 48% of those in the "patient contact" group and 44% for those in the "no patient contact" group. The unadjusted RR of a positive TST $\geq$20 mm was 1.24 (95% CI 1.16, 1.34) for workers with "patient contact" compared to those with "no patient contact." This risk is lower than that found among all converters regardless of reaction size, but still statistically significant.

Rates and Risk of TST Conversion by Year

To examine the annual variation of TST conversions and the potential effect throughout the hospital of the nosocomial TB outbreak in two in-patient wards, the rates and risks of TST conversion by year (1990, 1991, January 1 - September 30, 1992) were evaluated (Table 5). Additionally, those occupational subgroups with significantly elevated RR and at least 50 workers employed annually are included. These results are based on workers who **always** remained in the same occupational category during the calendar year. A total of 2,612 employees (96% of those working in 1990) stayed in the same occupational category in 1990; 3,034 employees (93% of those working in 1991) stayed in the same occupational category in 1991; and 3,193 employees (97% of those working in 1992) stayed in the same occupational category in 1992. Of note, the rates for 1992 are based on only nine months of available data, resulting in less statistical power and larger confidence intervals for this time period.

While the conversion rates varied from year to year for both exposure groups, the rate of conversions for the "patient contact" group remained approximately two-to-three-fold higher for the “no patient contact group” for each of the study years. Rates for specific occupations with “patient contact” that had significantly elevated risks of TST conversion also varied from year to year. Aside from nurses in the medium wards and emergency responders, the rates for all the groups were highest during 1991.

Positive TST Prevalence

One thousand one hundred seventy three workers were excluded from the analysis of conversion because they were either TST positive at the beginning of the study or upon first TST during the study period. For workers who were **always** in the same occupations/work areas during the study period, we compared the 3-year TST prevalence rates to the TST conversion rates. The 10 occupations/work areas with the highest prevalence rates are presented, in descending order, in Table 6. Aside from laundry workers, outpatient clinic staff, and respiratory therapists, who had higher prevalence, but lower incidence rates, the ranking of occupations tended to be similar for prevalence and incidence.

Risk to Workers <u>Ever</u> in an Occupational Classification

We also performed a person-time analysis that included all workers who were **ever** within specific occupational classifications or pay stations during the study period. This was done to increase our ability to identify smaller occupational groups that might be at risk for occupational TST conversion (data not shown). This analysis was then compared to the analysis of workers who **always** remained in the same job classification (see above section "Risk of Conversion"). This analysis revealed significantly elevated RRs of TST conversion among "low ward" nurses (RR 4.8; 95% CI 1.9, 12.5) and clerks (RR 5.3; 95% CI 1.8, 15.7), obstetrics/gynecology staff (RR 6.1; 95% CI 2.1, 17.8), and outpatient clinics staff (RR 4.0; 95% CI 1.9, 13.5). Otherwise there was very little difference in the rates or risk of TST conversion between the **ever** and **always** analyses.

Attributable Risk

For this study population, the risk of conversion attributable to occupational exposure (defined as contact with patients or patient lab specimens) was 58% with the outbreak wards excluded and 64% with outbreak wards included. Thus, potentially about 60% of the TST conversions among hospital workers would be prevented if occupational exposure could be eliminated. The prevalence ("p") used to calculate the attributable risk of occupational exposure was 73% (with the outbreak wards excluded (2362/3248) or included (2418/3304)).

DISCUSSION

Although the well-documented resurgence of TB in the United States in the late 1980s and early 1990s[8,9,10] continues to decline from a peak in 1992,[11,12] attention has been drawn to the risks to hospital workers and others involved in the care of patients infectious for TB. The risk of this potential occupational hazard is further heightened by the emergence of multidrug-resistant (MDR) strains of TB, which have been reported in 43 states, since 1993,[11] and have been responsible for at least 12 hospital outbreaks, with five deaths and 18 to 35 percent of exposed workers having documented tuberculin skin test conversions.[13] In 1994, the CDC recommended that hospitals throughout the country monitor rates of TB infection and disease among their employees and implement surveillance and control measures to protect those at increased risk.[4] Additionally, the Occupational Safety and Health Administration (OSHA) has proposed new regulations to protect an estimated 5.3 million workers who work in more than 100,000 hospitals and other settings with an increased risk of TB transmission.[14] It is important that hospital infection control personnel and other public health professionals better understand which workers are at highest risk for TB to ensure appropriate medical surveillance and to prioritize efforts to reduce exposure.

While it is now recognized that some groups of hospital workers (i.e., medical students, physicians, nurses) are at increased risk for occupationally acquired TB,[15] there have been relatively few published studies that have evaluated the risk among a wide range of occupations using an appropriate internal non-exposed comparison group and controlling for non-occupational, socioeconomic risk factors.[13] Much of the relevant literature has focused on reporting the risks of MTB transmission among physicians, nurses, and others with close patient contact during a TB outbreak or in the presence of a particularly infectious patient.[1,16,17,18]

Our results show a 3.6-fold increased risk of TST conversion among workers with direct exposure to patients or patient lab specimens as compared to workers with no direct patient contact. In addition to patient contact at work, demographic characteristics associated with an increased risk of TST conversion included male gender, non-white race, and decreasing hourly wage and duration of employment.

Although there is considerable evidence that workers who provide direct patient care are at greater risk for TB infection than workers who did not provide direct patient care, the results among studies are inconsistent.[1,17,19,20,21,22,23,24] One explanation for the differences may be variation in the admission rates of TB patients.[25,26] In institutions with fewer than 10 admissions for TB annually, the annual worker risk of infection was less than 0.2%, as compared to institutions like GMH, with more than 200 admissions for TB annually and an annual worker infection rate between 1 and 10 percent.[13] Additionally, several studies have used prevalence, instead of incidence, rates to identify occupational groups at risk.[21,25] Prevalence rates may be more reflective of prior occupational and nonoccupational infection.

Among the 18 occupational groups evaluated with potential TB exposure through patient contact or handling of patient specimens, we found statistically significantly elevated incidence rates of TST conversion among laboratory workers, nurses, clerks, pharmacy workers, phlebotomists, emergency room workers, emergency responders, and housekeepers. The findings of elevated risks of TB transmission among several of these occupations have been previously reported and appear to be indicative of workplace practices and exposures. In our study, the increased risk of TST conversion observed among ward nurses was related to a surrogate measure of occupational TB exposure. To our knowledge, this type of relationship has not been previously reported, although increased risks associated with certain occupations, not specifically linked with measures of TB exposure, have previously been found among nurses,[20,21,22] clerks,[22] ward-based dietary staff,[20] laboratory workers (i.e., microbiology technicians, histologists, and pathologists),[20,27,28,29,30] emergency department staff,[19] and housekeepers.[31,32] While increased risks among these occupations have been previously reported, the risks for most groups are not well characterized.

In addition to those occupations that previously were identified as having an increased risk, our study found significantly elevated risks for TST conversion among pharmacy workers, phlebotomists, and emergency responders (i.e., paramedics, emergency medical technicians). Our analysis of workers that were **ever** within specific occupational classifications or pay stations during the study period suggests that obstetrics/gynecology staff and outpatient clinics staff may also be at increased risk of conversion. Workers employed in these occupations may not have been previously identified, possibly due to small group sizes and perhaps a lower index of suspicion. For emergency responders, phlebotomists, obstetrics/gynecology staff, and outpatient clinics staff the increased risks are more readily apparent in terms of frequent and close patient contact. The increased risks found among pharmacy workers, if indeed occupationally related, are more difficult to explain and potentially more disturbing as these workers are not typically involved in direct patient care. Unfortunately, the specific activities and exposures that contribute to workers' increased risk cannot be identified by studies such as ours. For a few occupations, some explanations were offered by hospital employees. For instance, the increased risk observed among ward clerks may be related to exposure occurring when patients congregate in the ward clerk's area to use the telephones. The increased risk observed among pharmacy workers may be a consequence of exposure to persons with active TB who were waiting for medications in the out-patient pharmacy area.

Our study has several limitations. Only limited information was available concerning workers' BCG vaccination status, and no information was available concerning employees' country of birth, which is a recognized risk factor for TB, most likely resulting from reactivation of remotely acquired infection.[33] Also, the lack of 2-step testing creates difficulty in definitively evaluating the impact of the "booster" phenomenon. All of these limitations were addressed by our analyses using only workers with two or more documented negative TSTs prior to conversion. The results of these analyses did not affect our overall findings.

We used the hospital's definition of a TST conversion, which differed from current CDC guidelines, and thus may have overestimated the rate of TST conversion. Although this may have produced a systematic error in estimating rates, it is unlikely to introduce differential misclassification by exposure group. Our analysis of conversion rates by size supports this argument.

This study only addresses TST conversion rates for exposure groups defined by occupation or work area. This introduces the potential for misclassification of actual exposure, which could have affected the point estimates of RR. It is unlikely, however, that the magnitude of the potential misclassification bias would change the overall pattern of elevated risks for certain occupational groups. Also, since we were more likely to designate a worker as exposed if there was any uncertainty about the actual exposure, our point estimates of risk should be conservative. Lastly, TST data were not available for physicians, including residents and interns. Therefore, our results do not provide information regarding the occupational risk for these workers.

While findings from this study present a historical picture of nosocomial TB transmission among various groups of workers in this hospital, this data is useful to similar types of institutions trying to understand their own risks and essential to the development of appropriate worker protection guidelines. Our analysis of attributable risk during the study period suggests that potentially about 60% of the TST conversions among hospital workers would be prevented if occupational exposure could be eliminated. Additionally, this data provides GMH an invaluable baseline for comparison to more current rates to help determine the efficacy of TB control measures. For example, Blumberg, et al. performed a follow-up evaluation of TST conversions among hospital workers (not broken down by occupational categories) employed at GMH from January 1992, through June 1994.[34] The results of this study, further supported by our findings, suggest that new and expanded TB control measures, including administrative controls, engineering controls, and worker personal respiratory protection can reduce the risk of TB transmission among health care workers. Further, in our study, the demonstration of a high risk for TB infection among various occupational classifications with and without close patient contact has important implications for the development and implementation of strategies to prevent occupational transmission of TB. Effective TB transmission control is needed not only in areas of hospitals where patient care is taking place, but in all areas where employees may be exposed to infectious individuals. The results of our study also emphasize the importance of following the CDC recommendations[6] of including all health care facility personnel in TST programs, not just those providing patient care. As these recommendations are adopted, additional data concerning the risks of TB infection for various occupational groups employed within health-care-facilities under differing exposure conditions, should become available.

CONCLUSIONS

Workers with patient contact and those employed in certain occupational groups were at increased risk for occuptionally-acquired TB infection at the time of the NIOSH evaluation. Since this evaluation, the hospital has undergone many renovations and has implemented new TB control measures including additional negative-pressure rooms, expanded respiratory isolation of patients known or suspected to have TB, expanded employee education about TB, and use of submicron masks for workers entering respiratory isolation areas. Data analyzed by GMH staff show a subsequent reduction in TST conversions among hospital employees.[34]

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TABLE 1
Demographic characteristics by cohort, conversion status, and TST status prior to the study
HETA 92-0232-2767
Grady Memorial Hospital
Atlanta, Georgia

	n	Age* (SD)	Sex (% F)	Race (% nonwhite)	Years Employed*† (SD)	Wage*‡ $ / hr (SD)
Study cohorts						
No patient contact	886	38 (10.6)	64.5	78.6	10.7 (8.2)	11.2 (5.3)
Patient contact	2362	37 (9.7)	80.0	72.7	9.3 (8.0)	12.4 (5.5)
Conversion status						
TST Converters	156	37 (9.7)	64.0	84.0	7.6 (7.2)	11.3 (6.0)
Non-converters	3092	37 (10.0)	76.3	73.8	9.8 (8.1)	12.1 (5.4)
TST status at entry						
Study Group§	3248	37 (10.0)	76.1	74.5	9.7 (8.1)	12.1 (5.5)
TST+ at Entry‖	1173	43 (10.5)	75.9	87.9	12.0 (9.7)	12.2 (5.3)

* Means for age, years employed, and hourly wage are presented.
† Years of employment at end of study or date of termination.
‡ Average wage during study period.
§ Eligible workers for the study who were TST negative upon entry into the study group.
‖ Workers who were TST positive upon entry to the study and were thus excluded from the study group.

TABLE 2
Rate of conversion by demographic characteristics
HETA 92-0232-2767
Grady Memorial Hospital
Atlanta, Georgia

Demographic Characteristic	Converters / n	Rate (%)
Gender*		
Female	100/2460	4.1
Male	56/788	7.1
Race*		
White	25/835	3.0
Non-white	131/2413	5.4
Age (years)		
16 - 25	23/377	6.1
26 - 35	51/1120	4.6
36 - 45	48/1116	4.3
46 - 55	28/467	6.0
Over 55	6/167	3.6
Hourly Wage†,‡($)		
2.50 - 7.75	61/706	8.6
7.76 - 10.50	31/891	3.5
10.51 - 14.50	29/778	3.7
Over 14.50	35/870	4.0
Years Employed §		
Less than 2.5	33/601	5.5
2.5 - 5.5	57/820	7.0
5.6 - 13.7	33/905	3.6
Over 13.7	33/922	3.6

* T-test statistically significant at $p<0.05$
† Average wage during study period
‡ Chi-square for trend statistically significant at $p<0.05$
§ Years of employment at end of study or date of termination.

TABLE 3
Risk of conversion by cohort and those occupational groups with "patient contact"*
HETA 92-0232-2767
Grady Memorial Hospital
Atlanta, Georgia

Occupations / Work Areas	n	% Conversion	RR†	95% CI
Cohorts				
No patient contact	886	2.0	reference group	----
Patient contact	2362	5.8	3.6	2.2 - 5.8
Nurses				
All Nurses	525	5.5	6.5	3.2 - 13.1
Nurses High wards‡	96	12.5	12.6	5.4 - 29.6
Nurses Medium wards ‡	100	9.0	6.0	2.5 - 14.6
Nurses Low wards ‡	273	1.8	2.9	0.9 - 10.0
Clerks				
All Clerks with contact	114	6.1	4.3	1.6 - 11.9
Clerks High wards ‡	22	13.6	7.9	1.6 - 38.8
Clerks Medium wards ‡	16	12.5	12.2	2.5 - 59.8
Clerks Low wards ‡	50	2.0	1.9	0.2 - 15.1
Other Occupations				
Lab workers	106	6.6	5.8	2.2 - 15.1
Pharmacy	48	10.4	5.2	1.9 - 14.5
Phlebotomists	29	6.9	5.2	1.1 - 25.1
Emergency services	146	6.9	4.6	2.0 - 10.9
Housekeepers	103	12.6	4.4	1.9 - 10.0
Neonatal / Pediatrics	42	2.4	3.1	0.4 - 25.9
Food service workers	49	6.1	2.9	0.8 - 10.2
Emergency responders	145	6.9	2.8	1.1 - 6.7
Obstetrics / Gynecology	101	2.0	2.8	0.6 - 14.1

TABLE 3 CONTINUED
Risk of conversion by cohort and those occupational groups with "patient contact"*
HETA 92-0232-2767
Grady Memorial Hospital
Atlanta, Georgia

Outpatient clinics staff	85	2.4	2.5	0.5 - 12.1
Social services	131	3.8	2.2	0.8 - 6.0
Surgery / Anesthesia	121	2.5	2.0	0.6 - 7.1
Orderly / Patient escorts	34	8.8	1.5	0.4 - 5.5
Radiology	37	2.7	1.4	0.2 - 10.7
Respiratory Therapists	62	3.2	1.1	0.1 - 8.2
Dietician / Nutrition	20	none	–	–

* Analysis included only workers **always** employed in the same cohorts and occupational groups during the study period.
† All RRs (RR) were adjusted for age, race, gender, duration of employment, and TB incidence rate in the employees' zip code of residence.
‡ "High wards," 8 in-patient wards each with >30 positive pulmonary TB cultures, "Medium wards," 9 in-patient wards each of with 10 -30 positive pulmonary TB cultures, "Low wards," 14 wards each with less than 10 positive pulmonary TB cultures (1/89-5/92)

TABLE 4
Risk of TST conversion accounting for potential "Booster" phenomenon for "patient contact" groups with elevated risks*
HETA 92-0232-2767
Grady Memorial Hospital
Atlanta, Georgia

Occupations	Data **not** accounting for potential "Booster" phenomenon†		Data accounting for potential "Booster" phenomenon‡	
	Converters	RR (95% CI)§	Converters	RR (95% CI)§
All Nurses	52	6.5 (3.2-13.1)	38	6.0 (2.8-13.0)
Lab workers	7	5.8 (2.2-15.1)	6	6.1 (2.1-17.3)
Pharmacy	5	5.2 (1.9-14.5)	5	6.4 (2.2-18.1)
Phlebotomists	2	5.2 (1.1-25.1)	0	Not available‖
Emergency services	10	4.6 (2.0-10.9)	7	4.0 (1.5-10.9)
Housekeepers	13	4.4 (1.9-10.0)	10	4.6 (1.8-11.6)
All Clerks	17	4.3 (1.6-11.9)	16	4.3 (1.4-13.0)
Emergency responders	10	2.8 (1.1-6.7)	8	2.6 (1.0-6.9)

* Analysis included only workers **always** employed in the same occupations during the study period.
† Analyses including workers with 1 or more documented negative TSTs prior to conversion.
‡ Analyses including only workers with 2 or more documented negative TSTs prior to conversion.
§ All RRs (RR) were calculated using the "no patient contact" group as a reference group and were adjusted for age, race, gender, duration of employment, and TB incidence rate in the employees' zip code of residence.
‖ No convertors met the analysis criteria for this group.

TABLE 5
Annual Rate and Risk of Conversion for Study Cohorts and Specific Occupations/Work Areas*
HETA 92-0232-2767
Grady Memorial Hospital
Atlanta, Georgia

	1990			1991			1/1/92 - 9/30/92		
Study Groups	n	Rate (%)	Relative Risk (95%CI)	n	Rate (%)	Relative Risk (95%CI)	n	Rate (%)	Relative Risk (95%CI)
Group									
No patient contact	801	0.6	---	877	0.9	---	873	0.6	---
Patient contact	2078	1.1	---	2322	3.2	---	2266	1.9	---
Contact vs. No contact			1.8 (0.7, 4.8)			4.5 (2.2, 9.5)			4.0 (1.6, 10.3)
Occupations									
All nurses	565	1.5	3.5 (1.0,12.4)	607	3.2	12.2 (4.4, 33.8)	591	1.8	7.4 (2.1, 25.4)
Nurses, High†	85	2.4	4.7 (0.8,29.0)	100	7.0	19.7 (5.7, 65.5)	96	5.2	18.9 (4.5, 80.1)
Nurses, Med.†	98	5.1	8.2 (2.1,32.1)	110	4.6	8.2 (2.4, 27.0)	101	2.0	6.8 (1.1, 40.0)
Nurses, Low †	283	0.4	0.9 (0.1, 9.1)	290	1.4	4.9 (1.1, 23.1)	291	0.7	15.4 (0.9, 260.6)
Lab workers	106	0.9	1.4 (0.1,13.7)	107	2.8	5.2 (1.3, 21.2)	113	2.7	23.1 (3.6, 146.9)
Housekeepers	99	2.0	3.1 (0.5,19.2)	104	8.7	6.0 (2.0, 18.1)	98	4.1	2.9 (0.6, 12.8)
All Clerks (pt. contact)	119	1.7	3.3 (0.5,19.8)	128	3.1	5.3 (1.4, 20.1)	132	2.2	5.9 (1.0, 36.2)
All Clerks (no contact)	354	0.6	no exposure	367	1.4	no exposure	347	0.3	no exposure
Emergency Services	141	1.4	1.2 (0.1,11.3)	160	4.4	6.8 (2.3, 20.4)	154	1.3	6.2 (1.0, 40.2)
Emergency Responders	140	0.7	0.7 (0.1, 7.4)	147	2.7	3.0 (0.8, 11.5)	143	3.5	4.0 (1.0, 15.6)

* All relative risks (RR) were adjusted for age, race, gender, duration of employment, and TB incidence rate in the employees' zip code of residence using proportional hazards regression. Analysis included workers who were **always** employed in the same occupational group during the study period. Workers in wards 7B and 10B were excluded.

† "High wards," 8 in-patient wards each with >30 positive pulmonary TB cultures, "Medium wards," 9 in-patient wards each of with 10 -30 positive pulmonary TB cultures, "Low wards," 14 wards each with less than 10 positive pulmonary TB cultures (January 89-May 92).

TABLE 6
Prevalence and Incidence Rates for Specific Occupations/Work Areas*
HETA 92-0232-2767
Grady Memorial Hospital
Atlanta, Georgia

Occupations/Work Areas	Prevalence Rate (%)†	Incidence Rate (%) ‡
Clerks medium wards§	39.0 (11/28)	12.5 (2/16)
Nurses medium wards§	36.7 (79/215)	9.0 (9/100)
Nurses high wards§	34.9 (81/232)	12.5 (12/96)
Laundry	34.6 (18/52)	7.4 (2/27)
Housekeepers	31.8 (70/220)	12.6 (13/103)
Clerks high wards§	28.1 (9/32)	13.6 (3/22)
All nurses	27.3 (291/1067)	9.3 (52/562)
Pharmacy	27.4 (31/113)	10.4 (5/48)
Outpatient clinic staff	26.1 (37/142)	2.4 (2/85)
Respiratory therapists	23.8 (30/126)	3.2 (2/62)

* Analysis included workers **always** employed in the same occupational group during the study period; excluding workers in Wards 7B and 10B
† Prevalence rate = # TST (+) at the beginning of the study / total population.
‡ Incidence rate = # TST conversions during the study period / population at risk for TST conversion
§ "High wards," 8 in-patient wards each with >30 positive pulmonary TB cultures, "Medium wards," 9 in-patient wards each of with 10 -30 positive pulmonary TB cultures, "Low wards," 14 wards each with less than 10 positive pulmonary TB cultures (January 89-May 92)

APPENDICES

APPENDIX A

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Figure 1
Grady Hospital, HETA 92-232

Sulfur Hexafluoride Decay
Grady Hospital
Room 4B 20

August 9, 1994

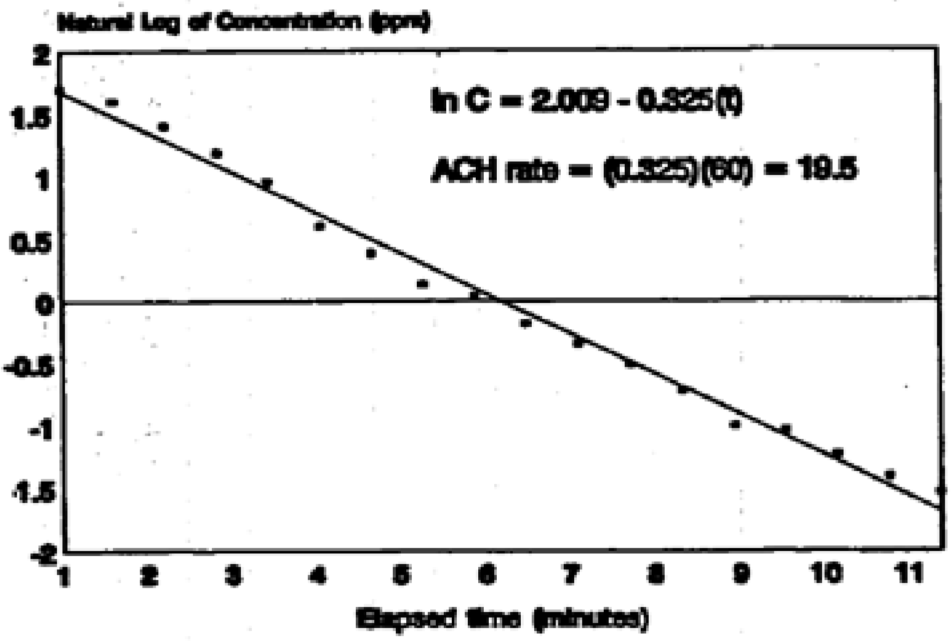

Figure 2 shows the concentration-decay plot for room 10D-32. The air-change rate, as estimated by the tracer-gas method, showed approximately 4.9 ACH, less than the minimum recommended 6 ACH. Nonetheless, the logarithmic concentration versus time plot yielded a straight line, also suggesting good air mixing in the area over the bed. Direct ventilation measurements were not conducted in this room. The low air exchange rate, which is probably typical of other "fan" rooms at Grady, demonstrates one of the inadequacies of this type of isolation room.

No SF6 was detected outside either room as long as the doors were closed. This finding was consistent with the smoke tests, which indicated both isolation rooms were under negative pressure. When the doors to room 4B-20 were opened, SF_6 was detected at the nursing station within 5 minutes, despite smoke tests showing the room was under negative pressure. This finding indicates the importance of keeping the doors to isolation rooms closed. The open-door SF_6 test was not conducted on room 10D-32.

If you have any questions regarding our evaluation or this report, feel free to telephone me at (404) 331-2396.

Sincerely yours,

John A. Decker

John A. Decker, M.S
Industrial Hygienist

Enclosure
cc:
Henry Blumberg, Grady
John McGowan, Grady
Katherine Cox, AFSCME

did not overpower the air velocity. This procedure was performed at the top, middle, and bottom of the closed door. If smoke traveled into the room at all three door locations, the room was designated to be under negative pressure. If the smoke was blown outward or stayed stationary at any door location, the room was deemed to be under positive pressure.

Evaluation Criteria

The American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE) and the American Institute of Architects (AIA) have guidelines for various ventilation parameters in hospitals.[5,6,7] A comprehensive discussion of these guidelines can be found in a May 1992 interim report to Grady Hospital.

Recommended ventilation rates in hospitals are frequently expressed in terms of air changes per hour (ACH). An ACH is defined as the theoretical number of times that the air volume of a given space will be replaced in a one-hour period by air supplied to the space or transferred to the space from adjacent spaces. However, the terminology is misleading; air is not actually "changed" the theoretical number of times per hour, even if there is perfect mixing.

For isolation rooms, ASHRAE recommends a minimum of six ACH with two of the six ACH being outside air. All air should be exhausted directly to the outside, and the room should be maintained under negative (lower) pressure with respect to adjacent areas. Negative pressure is attained by exhausting more air from an area than is being supplied. According to draft guidelines issued by the Centers for Disease Control and Prevention, negative pressure can be achieved by balancing the room supply and exhaust flows to set the exhaust flow to a value 10% (but no less than 50 cfm) greater than the supply.' The guideline also states that a pressure differential of 0.001 inch of water and an inward air velocity of 100 feet per minute are minimum acceptable levels.

Results and Discussion

Figure 1 shows the concentration-decay plot for room 4B-20. The tracer-gas method indicated the ventilation system provided approximately 19.5 ACH, well in excess of the minimum recommended 6 ACH. The air-change rate calculated from ventilation measurements (using an air flow hood) and room dimensions indicated approximately 18.3 ACH. Since the volume of objects in the room were not subtracted from the room volume, it was expected that the ventilation-measurement method would yield a slightly lower (and less accurate) estimate of air change rate compared to the tracer-gas method.

In addition to air-change rate, the tracer-gas method provided some infon-nation on air mixing in the room. The logarithmic concentration-decay plot yielded a straight line, suggesting good air mixing at the location where SF6 concentration was measured (over the bed).' Because the air change rate calculated from ventilation measurements was similar to that calculated from tracer-gas decay, it can be inferred that air mixing throughout the entire room, on average, was good.

Measurement of SF_6 was accomplished with a Brüel & Kjær Type 1302 direct-reading multi-gas monitor. The principle of detection is infrared absorption at a specific wavelength with subsequent analysis via the photoacoustic effect. The concentration range for the instrument was approximately 0.050 to 600 parts per million (ppm) SF_6.

SF_6 was released into the isolation room at approximately 2 liters per minute (Lpm). The SF_6 concentration was monitored continuously (approximately every 45 seconds), and a fan was used to ensure uniform mixing throughout the room. When the concentration reached 6-7 ppm., the gas was turned off, the fan was turned off, and the time was recorded. The concentration-decay was then measured inside the room (over the bed) until the concentration dropped between 1/8 to 1/10 the original room concentration. A peak concentration of 6-7 ppm was used rather am 2-3 ppm as originally planned due to the limit of detection of the Brüel & Kjær monitor for SF_6. The fan was turned off during the concentration-decay phase of the evaluation.

A NIOSH investigator located outside the room collected air samples in air-sampling bags 5 minutes, 15 minutes, and 20-30 minutes following initial release of the SF_6 gas. The air-sampling bags were filled using Gillian high-flow battery-powered air pumps. Following completion of the concentration-decay measurements, the concentrations of SF6 in the sample bags were measured.

The natural log of SF_6 concentration versus elapsed time was graphed, yielding a straight line plot. The air change rate is equal to the slope of the line.[4] Since the elapsed time was plotted in terms of minutes, the slope was multiplied by 60 to convert "air changes per minute" to "air changes per hour."

For comparison purposes, supply and exhaust airflow for room 4B-20 was measured with a Shortridge Instruments Airflow Hood. Room pressurization was determined with a smoke tube, and room volume was determined by actual measurements. From this information, the air change rate for the room was calculated. For room 10D-32, the configuration of the RTU and axial fan did not allow ventilation measurements or calculation of the air change rate. However, pressurization of the room was evaluated with a smoke tube.

During the evaluation, the doors to the isolation rooms were closed at all times. However, we were also interested in evaluating the potential for contaminants to migrate from a properly functioning isolation room if the room doors were left open. After completing the initial evaluation of room 4B-20, SF_6 gas was released inside the room while the doors were left open for approximately 5 minutes. During this time, a NIOSH investigator walked in and out of the room continuously. Another NIOSH investigator measured the SF_6 concentration outside the room, near the nurses station.

To check the rooms for negative pressure, the smoke tube was held parallel to the door and smoke was discharged from the tube slowly to assure that the velocity of the smoke

DEPARTMENT OF HEALTH & HUMAN SERVICES

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August 25, 1994
HETA- 92-232

Ms. Pat Moore
Nurse Epidemiologist
Epidemiology Department
Grady Hospital
P.O. Box 26001

Dear Ms. Moore:

On August 9, 1994, we conducted a tracer-gas ventilation study of two isolation rooms at Grady Hospital. The tracer-gas was used to determine room air change rates and the potential for contaminants to migrate from the rooms.

A new isolation room on the fourth floor (4B-20) and an older "fan" room on tenth floor (10D-32) were evaluated. Room 4B-20 featured an anteroom and 100% exhaust of room air to the outside. Room 10D-32 was a regular patient room having a window-mounted axial fan blowing air out the window to maintain the room under negative pressure. Room 10D-32 also had a "recirculating thermal unit" or RTU, which contained a recirculation fan, filter, and cooling coils for treating the combined supply and return air. The unit introduced some outside air from the hospital's ventilation system.

Methods

The tracer-gas evaluation was conducted according to the American Society for Testing and Materials (ASTM) Standard E741-93, "Standard Test Methods for Determining Air Change in a Single Zone by Means of a Tracer Gas Dilution," using sulfur hexafluoride (SF_6) tracer gas.[1] The concentration-decay test method, described in the ASTM Standard, was used. The air change rate was determined by measuring the logarithmic rate of decline in SF_6 concentration. This method assumes the tracer gas follows a first-order exponential-decline in concentration. The specific procedures are discussed later in this section.

The NIOSH Recommended Exposure Limit (REL) for SF_6 is 1000 ppm, expressed as a 10-hour time-weighed average.[2] SF_6 is considered pharmacologically and toxicologically inert.[3] At high concentrations, SF_6 is a simple asphyxiant. The source SF_6 for this project was 1 % SF_6 in nitrogen (Matheson Gas Products, Morrow GA), released from a compressed gas cylinder using a regulator. NIOSH Human Subjects Review Committee approval is not required for the use of SF_6. Although the concentration of SF_6 in this study was less than 8 ppm, unoccupied rooms were chosen to minimize potential disruption to staff and patients.

APPENDIX C

HAZARD EVALUATION AND TECHNICAL ASSISTANCE
INTERIM REPORT
HETA 92-232
GRADY HOSPITAL
ATLANTA, GEORGIA

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I. INTRODUCTION

The National Institute for Occupational Safety and Health (NIOSH) received a request dated April 16, 1992, for a Health Hazard Evaluation (HHE) at Grady Memorial Hospital (GMH), Atlanta, Georgia, from a representative of the American Federation of State, County, and Municipal Employees (AFSCME) union. The request raised a number of issues associated with the risk of transmission of tuberculosis (TB) to hospital employees and sought recommendations concerning possible strategies to reduce this risk.

This report contains the results of a ventilation evaluation and preliminary epidemiologic investigation conducted on May 14-15, 1992. The objectives of the ventilation evaluation were two-fold: 1) to identify current ventilation parameters that may contribute to transmission of TB in the hospital, and 2) to provide baseline data for NIOSH and Centers for Disease Control (CDC) epidemiologic studies that will attempt to identify and quantify factors that might contribute to transmission of TB among health care workers.

An evaluation by hospital management of TB skin test conversions among employees between March 1991 and February 1992, revealed a conversion rate of about 1.4%. According to hospital management, the number of patients with TB has not changed significantly over the past few years. During annual TB screening by GMH Employee Health Services in January 1992, there appeared to be increased skin test conversions among health care workers on Wards 7B and 10B. In response, on February 28, 1992, GMH formed a TB Task Force to review procedures and the physical plant. In March and April 1992, GMH Employee Health Services offered TB skin tests to all hospital employees, emphasizing those employees working in identified high risk areas. Additionally, in April 1992, hospital management requested the CDC to investigate a possible TB outbreak among hospital employees in Wards 7B and 10B. The CDC Epi-Aid investigation is currently being conducted by the National Center for Infectious Diseases, Hospital Infections Program (NCID/HIP), and is being performed in collaboration with the NIOSH HHE.

Evaluations of the ventilation systems were conducted on Ward 7B and Ward 10B. In addition, walk-through surveys of the Medical Emergency Clinic (MEC) Infectious Diseases Clinic, and the Pulmonary Function Lab were conducted.

II. BACKGROUND

GMH was designed in the 1940's and constructed in 1956. The hospital is a 1,200,000-square-foot facility, with 1162 beds and a staff of about 5200 people. The hospital is currently undergoing extensive renovation.

Wards 7B and 10B

Ward 7B is a general medical ward having a capacity of approximately 36 beds. There are two 4-bed rooms, one 8-bed room, and nine 2-bed patient rooms. Seven of these nine rooms on the ward are designated as "negative pressure" rooms (a discussion of "negative pressure" rooms will follow). Known or suspected tuberculosis (TB) patients may be assigned to these "negative pressure" rooms (when TB cases are assigned, only one patient is assigned per room).

Ward 10B, a medical oncology and transplant patient ward, is similar in layout to Ward 7B. Ward 10B has a reverse isolation room which is positively-pressured and supplied with high efficiency particulate air (HEPA) filtered air. There are no "negative pressure" rooms on 10B. Suspected or known TB patients are not permitted on Ward 10B.

Supply air is provided to Wardds 7B and 10B by separate heating, ventilation, and air conditioning (HVAC) units (AC-078 and AC-079 for Wards 7B and 10B, respectively) located in the 6A mechanical sub-floor. The units, provided 100% outside air to the hospital. Outside air passes through coarse filters and then preheat coils before entering the mechanical room and the supply fans. The HVACs contain heating and cooling coils, but not additional filters. Air is exhausted from the wards via exhaust fan VE-2B, located on the top (18th) floor. The system exhausts air from the 4th through the 10th floor of the hospital's B Wing). The supply and exhaust systems are interlocked. A shut-down of any one of the systems results in a shut-down of the remaining systems. Engineering staff indicated that these units, along with all other air handling systems, are scheduled for replacement. To date, only two systems serving the basement area have been replaced with new equipment.

The main air supply duct traverses the length of Ward 7B's and 10B's main corridors. Smaller branch ducts feed off the main supply and provide outside air to each patient room via a "recirculating thermal unit" or RTU. Each unit contains a recirculation fan, filter, and cooling coil for treating the combined supply and return air. The system draws air over coils and introduces some outside air (reportedly 50 cubic feet per minute [CFM]). The RTU units have low efficiency Viskon-Aire Filt-R-Sleeve® polyester filters which are reportedly changed monthly. The RTU fan cannot be turned off or adjusted by the occupant. A room thermostat controls the chilled water supply to the RTU but has no effect on air volume. The RTUs are positioned above the doorway. Each room has a separate radiant heat unit.

Each room is exhausted through a louvered wall vent, which draws air from the room and delivers it to the central B wing exhaust shaft that exits the building on the roof. According to a Grady engineer, booster fans have been installed in some areas to ensure adequate room exhaust.

Some patient rooms on each floor have been converted to "negative pressure" rooms. These rooms are regular patient rooms that have had a Dayton Model 2C634B utility shutter-mounted axial propeller exhaust fan (7" blade diameter, design capacity of 130 CFM) installed in the window. The fans simply discharge unfiltered air to the outside. Most of the fans are plugged into nearby electrical sockets; some are hard-wired. Since January 1992, the engineering department has converted about 60 rooms. About 2-3 rooms a week are being converted, and a total of 72 are planned. These rooms are scattered throughout the medical /surgical wards of the hospital. The rooms are dual purpose, and when used for isolating infectious patients, signs are posted on the door, and staff members are asked to keep the doors and windows closed. A room must be "certified" by the Engineering Department before it is designated as a "negative pressure" room. Currently, there are no written certification protocols. Certification consists of smoke tests at the room door to verify direction of airflow. "Negative pressure" rooms should not be confused with the five "isolation" rooms (B635, C635, D631, E513, and E405) at GMH, which were originally designed as hospital isolation rooms.

Medical Emergency Clinic

The main Medical Emergency Clinic (MEC) area (original section) is served by AC-5, which is a constant volume HVAC system designed to provide 20% outside air and 80% recirculated air. The return air is ducted (no common plenums such as false ceiling or mechanical rooms) from a large wall grille in the main corridor. Although there are a number of supply diffusers throughout the MEC, the system is equipped with only one large return intake located behind a bench for waiting patients.

All the rooms in the MEC are at neutral pressure and, for ventilation purposes, the entire MEC should be considered a common area. At the time of our visit, the main MEC area was extremely crowded with both patients and health-care workers. Both sides of the main corridor were lined with patients lying on portable beds.

A single story addition has been recently added to the MEC. This area is used as a holding ward for observation and/or monitoring of patients. The MEC addition is served by two separate rooftop HVAC units that also recirculate air. We did not examine these units.

In an attempt to reduce TB air levels, the hospital installed a number of NSA 7100A Environmental Air Systems (Memphis, TN) portable HEPA filtration units throughout the MEC, MEC addition, and the Surgical Emergency Clinic (SEC). The units have a rated airflow of 120 CFM. Maintenance procedures, including filter change procedures and frequencies, have not yet been established at the hospital.

<u>Pulmonary Function Laboratory</u>

Bronchoscopy is conducted in this area. Patients wait in the hallway outside the lab prior to examination. One patient at a time is treated, and it is often unknown if the patient has TB. The room has a window fan and a wall-mounted air-conditioner. There are two doors, one leading from the hallway, and the other exiting into the main corridor. The room is designed to be under negative pressure, and there are plans to re-model the area to accommodate up to three patients at the same time. A window exhaust fan has been installed to assist in maintaining the room under negative pressure (air flowing into the room). GMH personnel were concerned that when the air-conditioner was on, the room air pressure gradient became positive (i.e., air flowing out of the room).

<u>Infectious Diseases Clinic</u>

The Aerosol Inhalation and Infusion Room in the Infectious Disease Clinic (IDC) is in the process of being relocated. This is a multi-purpose room where pentamidine aerosol treatments and intravenous infusion therapies are provided to AIDS patients. No isolation facilities are available, and there are generally several health care workers also in this room. GMH previously provided up to 400 pentamidine treatments per month and currently provides 25-40 treatments per week. Each treatment lasts approximately 20 minutes. The room was modified to have a negative pressure with respect to the main corridor and the adjacent holding room. Two return air vents connected to return air ducts supplying other areas have been blocked by plexiglass covers. A window exhaust fan was installed to assist in maintaining the room under negative pressure.

III. EVALUATION CRITERIA

Hierarchy of Control Strategies

In the hospital setting, primary importance should be placed on early identification, treatment, and isolation of infectious TB patients, and correct application of principles of ventilation (both local and general). The use of germicidal ultraviolet radiation and personal protective equipment (respirators) should be viewed as ancillary control measures.

The risk of TB transmission in any setting is proportional to the number of viable TB bacilli in the air. All suggested control measures may reduce a worker's exposure to TB to some extent; however, there are no currently-available methods to quantify the degree of reduction that may be achieved by each control measure. Although ventilation is frequently relied upon to control TB in the health-care setting, ventilation systems sometimes can be complex and difficult to evaluate. Satisfactory performance of ventilation systems requires oversight by engineers or industrial hygienists. Incorrect design applications or inadequate maintenance can, in fact, increase the risk of TB transmission.[1,2] Consensus guidelines for ventilation and ancillary measures of worker protection have been formulated and are based on what are believed to be the most effective combination of feasible control strategies.[4,5]

Ventilation Considerations

There are two types of ventilation used for control of airborne transmission of TB; general dilution ventilation and local exhaust ventilation. General dilution ventilation provides a general exchange of contaminated indoor air with uncontaminated air thereby diluting the airborne concentration of the infectious agent and reducing potential exposures for workers and other susceptible persons (i.e., patients and visitors). Each of these types of ventilation is explained more fully below.

General Dilution Ventilation

General dilution ventilation performs two functions. The first is to provide sufficient outside air to maintain comfort. The American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE) recommends for hospitals a range of 15 to 30 cubic feet per minute (CFM) per person of outdoor air.[3] The second function of general dilution ventilation is to provide sufficient exchange of potentially contaminated air with clean air to reduce the risk of infection. ASHRAE and the American Institute of Architects (AIA) suggest airflow ranging from 4 to 15 air changes per hour (ACH), depending on the functional area of the hospital.[4] These guidelines are provided in terms of pressure relationships to adjacent areas, minimum outdoor air and total air changes, exhaust location, and recirculation restrictions.

In addition to supplying the specified airflow, ventilation systems should also provide satisfactory airflow patterns both from area to area and within each room. Air flow should be from "clean" to "less clean" areas, such as from hallways to treatment rooms. This can be accomplished by creating negative (lower) pressure in the area into which flow is desired relative to adjacent areas. Negative pressure is attained by exhausting more air from the area than is being supplied. For large areas this will require careful balancing of the ventilation system.

Within a room or small area, a ventilation system should be designed to: 1) move air to all areas of the room (prevent stagnation of the air), 2) prevent short circuiting of the supply to the exhaust (i.e., passage of air directly from the supply site to the exhaust point without mixing of room air), and 3) direct the clean air past the worker without recirculation within the room. These conditions are not always achievable but should be attempted to the fullest extent feasible. One way to accomplish this is to supply low velocity air at one end of a room and exhaust it from the opposite end. Another method is to supply low velocity air near the ceiling and exhaust it near the floor. However, air flow patterns are also affected by air temperature, the precise location of supply vents and exhaust vents, diffuser design, the location of furniture, movement of workers, and the physical configuration of the space. Each room or space must be evaluated individually.

Ideally, ventilation systems used in areas where *Mycobacterium tuberculosis* may be present should supply non-contaminated air (a portion should be outside air), discharge exhaust air to the outside, and should not recirculate air back into the facility. Where TB may be present, an area of the hospital should be selected where the ventilation can be optimized or simply rebalanced to provide the desired ventilation parameters. Where this is not possible, less desirable alternative approaches may be used. Rooms connected to recirculating ventilation systems could utilize high efficiency particulate air (HEPA) filtration in the room exhaust or filter the air before it is recirculated. In cases where a room has no ventilation, a HEPA-filtered recirculating duct system for that room might be considered. In no case should a room or area without mechanical exhaust ventilation be used for patients with *M. tuberculosis.*

Recommended ventilation rates in hospitals are frequently expressed in terms of air changes per hour (ACH). An ACH is defined by the theoretical number of times that the air volume of a given space will be replaced in a one-hour period. Assuming perfect mixing, a rate of six ACH would require 46 minutes to remove 99.0% of contaminants from a room.[6] Hence, the air is not actually "changed" six times per hour. The amount of air required to maintain six ACH in a smaller room will be less than a larger room.

For purposes of general ventilation, all supplied air does not have to be outside air. For example, AIA recommends that operating rooms be ventilated with a minimum of three ACH outside air with a minimum total of fifteen ACH. The remaining twelve air changes only need be "clean" air (often referred to as "transfer air"), not necessarily outside air.

The AIA ventilation recommendations are presented in Table 1 (see next page). Hospital isolation rooms should provide six ACH with all air exhausted directly to the outside. Exhaust locations should not be near areas that may be populated (e.g., sidewalks or windows that may be opened). Exhaust points should also be away from air intakes, so that exhaust air is not circulated back into the facility. The rooms should be under negative pressure with respect to adjacent areas.[4,7] For isolation rooms, ASHRAE has similar recommendations, except that a recommendation that two of the six ACH should be outside air is included.[5] ASHRAE also recommends a minimum of 25 cubic feet per minute/person (CFM/person) for patient rooms.[3]

Local Exhaust Ventilation

Local exhaust ventilation captures the infectious agent in the immediate field of an infectious patient (i.e., scavenging booths or tents) without exposing other persons in the area. It is the preferred type of ventilation because the TB organisms are removed before they can disperse throughout the work area. Local exhaust ventilation is used most effectively in a fixed location. The hood portion of a local exhaust system may be of exterior design, where the infection source is near but outside the hood, or enclosing, where the infectious source is within the hood. Enclosures (booths) are available for aerosol-generating activities, such as sputum collection and aerosol therapy. These devices may be exhausted directly to the outside, or they can exhaust through a HEPA filter back into the room.

Table 1

Ventilation Evaluation Criteria[1,2]
Grady Hospital Atlanta,

Area Designation	Air movement relationship to adjacent area	Minimum air changes per hour outside air	Minimum total air changes per hour	Recirculated by means of room units[3]	All air exhausted directly to outside
Operating room	Out	3	15	No	-
Delivery room	Out	3	15	No	-
Newborn nursery	-	1	6	No	-
Recovery room	-	2	6	No	-
Intensive care	-	2	6	No	-
Isolation room	In	-	6	No	Yes
Isolation anteroom	Out	-	10	No	Yes
Patient room	-	-	2	-	-
Examination room	-	-	6	-	-

1 Selected ventilation guidelines adapted from the American Institute of Architects Guidelines for Construction and Equipment of Hospital and Medical Facilities (reference #4).

2 This table covers ventilation for comfort, as well as for asepsis and odor control in areas of acute care hospitals that directly affect patient care. Areas where specific standards are not given shall be ventilated in accordance with ASHRAE Standard 62-1989, "Ventilation for Acceptable Indoor Air Quality Including Requirements for Outside Air."

3 Because of cleaning difficulty and potential for buildup of contamination, recirculating room units shall not be used in areas marked "No." Isolation and intensive care unit rooms may be ventilated by reheat induction units in which the primary air supplied from a central system passes through the reheat unit.

IV. METHODS

On May 14, 1992, a walk-through tour was conducted of the main mechanical units (AC-078, AC-079, and AC-005) supplying air to Wards 7B and 10B, and the MEC. The cooling coils and reheat coils in the supply systems were visually inspected. The exhaust systems (VE-213 - serving 7B and 10B and ACE-7J - serving MEC) were evaluated from a design standpoint.

Ward 7B

Three "negative pressure" rooms (B-727, B-729, B-734) were evaluated on May 14 and 15, 1992. The airflow rates from the window fan exhausts were measured in selected areas on Ward 7B using Shortridge Instruments, Inc. Airdata Multimeter (ADM-860) electronic micromanometer (serial number M91711, calibrated September 16, 1991).

Exhaust measurements were obtained under the following four conditions: 1) fan on, door closed (proper room conditions for isolated patients); 2) fan off, door closed; 3) fan on, door open; and 4) fan off, door open. Room exhaust airflow rates were calculated by estimating the air velocity at eight individual points on the face of the exhaust (using the VelociCalc TSI) and multiplying the average velocity value by the area of the exhaust. To adjust for the effect of the exhaust grille on velocity measurements, the corrected, estimated air velocity at each point was calculated by applying a correction factor of 0.73 to the measured velocity.[8]

Outside air supply rates to the rooms were measured with a VelociCalC TSI Plus velometer (model 8360, serial number 204065, calibrated April 1992). Air supply rates were measured with the window fan on and the door closed. Five cross- sectional velocity measurements were made in the supply duct and the volumetric airflow rate was calculated by multiplying the average air velocity by the cross-sectional duct area.

Smoke tests were conducted to subjectively evaluate the relative pressures of the rooms with respect to the main ward corridor with the window fan running. The direction of smoke was observed at the cracked doorway (open approximately one inch).

Room B-735 (Head Nurse's Office, previously an anteroom), which is flanked on both sides by "negative pressure" rooms B-734 and B-738, was evaluated qualitatively with smoke tubes (the direction of air movement was observed with smoke). The room had doors leading to the adjacent "negative pressure" rooms.

For the rest of the rooms on Ward 7B, the direction of airflow was observed using smoke tubes to qualitatively determine the pressure relationships of the rooms with respect to adjacent corridors and open areas. The direction of smoke was observed at the cracked doorway.

The measured values and estimates of the outdoor air supplied to each area were then compared to guidelines such as the 1987 *Guidelines for Construction and Equipment of Hospitals and Medical Facilities* published by the American Institute of Architects (AIA) and American Society of Heating, Refrigerating, and Air-conditioning Engineers (ASHRAE) Standard 62-1989, *Ventilation for Acceptable Indoor Air Quality.*

Ward 10B

Five rooms on Ward 10-B were inspected to determine if air was exiting any of the room exhausts (air coming into the room through the exhaust rather than leaving the room). This was accomplished by observing the direction of airflow with smoke tubes. There were no isolation or "negative pressure" rooms present on this ward.

MEC

The MEC was evaluated qualitatively by reviewing the ventilation system design, The MEC is scheduled to move to a new area in June 1992. No ventilation measurements were taken in this area.

Pulmonary Function Area and Infectious Diseases Clinic

The direction of airflow was observed using smoke tubes to qualitatively determine the pressure relationships of the rooms with respect to adjacent corridors. The direction of smoke was observed at the cracked doorway (open approximately one inch).

V. RESULTS AND DISCUSSION

Ward 7B

The results of airflow measurements and airflow direction in rooms B-727, exhaust on all three rooms ranged from 98 to 105 CFM, whereas the room exhaust was quite variable. The room exhaust in B-727 and B-734 was 14 CFM and 200 CFM, respectively (measurements reported are those when the window fan was on and the door was closed). The exhaust in room B-729 was found to reverse direction when the window fan was on and the door was closed. This could potentially allow contaminants exhausted from other areas to enter the negative pressure rooms.

Air volume measurements on the supply duct to rooms B-727 and B-729, which were supplied by 4-inch ducts, showed less than the ASHRAE recommended 25 CFM/person, even when only one patient was present. Room B-734, serviced by an 8-inch duct, was receiving about 38 CFM of outside air.

Table 2

Ventilation Results
"Negative Pressure Rooms" - Ward 7B
Grady Hospital
Atlanta, Georgia

	Room B-727	Room B-729	Room B-734
Window fan exhaust (CFM)	-105	-99	-98
Room Exhaust (CFM) with	-14	+ 17[1]	-200
Room outside, air supply in CFM (amount entering return thermal unit)	+20	+14	+35
Theoretical air changes per hour calculated on total exhaust	4	3	~ 10
Pressure at door	Variable[2]	negative	Variable[3]
Meets all AIA andASHRAE recommendations.	No	No	No

Negative values indicate that air was exiting the room. Positive values indicate that air was entering the room.

1 Air was entering the room from the exhaust vent (air was moving in the wrong direction).

2 The direction of airflow at the top of the door was into the room (negative), at mid-level it was neutral, and at floor level it was out of the room (positive).

3 The direction of airflow was neutral at the top of the door. At mid-level and at floor

Table 2 (at the right) also lists theoretical air changes per hour (ACH), based on total room exhaust, for each of the rooms, Room B-734 had a greater number of ACH because of the greater room exhaust air flow rate.

The direction of airflow in room B-727 at the top of the doorway was into the room (negative), at mid-level it was neutral, and at the bottom of the doorway the airflow was out of the room (positive). Room B-729 was negative at all locations. Room B-734 was neutral at the top of the door, and negative at other locations. An explanation of these findings was not apparent. However, the direction of air movement at the door may be influenced by the RTU unit above the door and environmental conditions outside (air blowing on the side of the building, reducing the window exhaust).

The RTU servicing room B-734 had no room recirculation return air grille; however, the unit had a cooling water loop as well as a recirculating fan that was found to be operating when the unit was opened. Grady personnel indicated that the RTU filters were changed monthly. However, the filters in rooms B-727 and B-734 showed considerable build-up of dust, and it did not appear to have been cleaned for a long period of time. The walk-through inspection of the main mechanical room indicated that the HVAC systems were relatively clean.

Between rooms B-734 and B-738 is the Head Nurses Office (room B-735) which has doors on each side leading into both patient rooms, as well as a door to the main corridor. The Head Nurse's office is a converted anteroom that previously served patient rooms B-734 and B-738. This arrangement is typical for all the wards. The nurses office has an RTU for air supply and a ceiling exhaust at the back of the room. The exhaust vent, however, was not functioning and appeared to be functioning as a supply vent. Pressure evaluations made by observing the movements of smoke and tissue paper indicated that with the nurses corridor door open, and rooms B-734 and B-738 operating as designed, the nurses office was slightly positive with respect to the patient rooms. However, with the head nurses door closed, the nurses office was slightly negative with respect to the patients room, allowing contaminants to spread from the "negative pressure" rooms to the office. The office was positive with respect to the corridor. No explanation was found for this finding. GMH personnel were contacted to investigate this issue further.

The direction of airflow for the rest of the rooms on Ward 7B are presented in Table 3. As discussed previously, B-727 and B-734 ("negative pressure" rooms) were not under negative pressure during all conditions. The remaining four "negative pressure" rooms (those that had the window fans on) were under

Ward 10B

Smoke tests were used to visually evaluate the room exhaust in the rooms on this ward. The tests showed that all room exhausts were functioning properly with the door either closed or open. In the nurses computer room, smoke tube tests showed that the room exhaust reversed flow momentarily when the door was closed and the window opened.

<u>Pulmonary Function Lab</u>

Smoke tests indicated that the room was negative with respect to both the corridor and the hallway under all air-conditioning operational modes (vent on/off, normal and maximum).

<u>Infectious Disease Clinic</u>

Smoke tests indicated that the Aerosol Inhalation Room was negative with respect to the corridor and adjacent holding room.

Table 3

Direction of Airflow
Selected Rooms on Ward 7B
Grady Hospital
Atlanta, Georgia

Room Number	Top of Door	Midlevel of Door	Bottom of Door
B-709 (fan on)	-	-	-
B-710 (fan on)	-	-	-
B-715 (no fan)	-	-	+
B-718 (no fan)	-	+	+
B-727 (fan on)	-	±	±
B-728 (fan off)	-	+	+
B-729 (fan on)	-	-	-
B-730 (Doctors' office - no fan)	+	+	+
B-733 (Nurses' work room - no fan)	-	±	+
B-734 (fan on)	±	-	-
B-735 (no fan)	+	+	+
B-738 (fan on)	-	-	-

- Air movement into the room

+ Air movement neutral or indeterminate

Smoke tests at the blocked return air vents showed that, in an area where the vent had separated from the wall approximately one-half inch, room air was bypassing the blocked return-air vent. The air escaping into the return air vent could have contaminated other areas of the building.

VI. NIOSH EPIDEMIOLOGIC INVESTIGATION

To assess the feasibility of conducting an epidemiologic investigation of TB transmission among health care workers in various job categories, NIOSH medical officers met with GMH administrators from Employee Health Services, Human Resources, and Clinical Laboratory Services to review records and record-keeping practices. NIOSH investigators reviewed: (1) employee health records pertaining to TB skin testing, (2) personnel records to evaluate the availability of information describing employee's job titles and work locations over time; and (3) clinical laboratory records to evaluate the hospital locations of patients with positive TB cultures over time. Preliminary results of this investigation indicate that the information needed to perform an epidemiologic study is most readily available for the time period covering 1989 through 1992. Additionally, information from prior years may become available for analysis.

VII. PRELIMINARY RECOMMENDATIONS

1. Until the hospital renovation is completed, the use of window fans to produce negative pressure in patient rooms, while not the optimal control measure, should be continued.

   A qualified electrician should review all window fan installations. The window exhaust fan motors were very hot to the touch, possibly due to excessive current draw. This situation potentially creates a contact and possible fire hazard. Additionally, many of the fans were not hard-wired, and could be unplugged or turned off by anyone.

   Centrifugal "squirrel cage" fans might be considered as an upgrade, since they can develop more static pressure than axial fans, have low space requirements, and are quieter in operation.

2. The room exhaust system should be fully evaluated to ensure that the systems will not reverse flow under any room conditions (e.g., windows or doors open/closed, exhaust fans on/off), and any deficiencies found should be corrected. In-line duct booster fans should be evaluated to ensure they are not creating pressure fluctuations.

3. The hospital's "negative pressure" rooms may not be under negative pressure at all times. GMH should consider installing continuous room pressure monitors for the rooms designated for infectious patient isolation (relative pressure differential between the patient room and the main corridor). These could be designed to provide a visual indicator to hospital staff that negative pressure is maintained.

4. The criteria used by GMH to certify a room for infectious patient isolation should be expanded and prepared in written form. The criteria should include quantitative measurements of exhaust and supply air, as well as visual indicators such as generated smoke. Periodic re-certification should also be considered.

5. The airflow rate from the portable HEPA filtration units is probably too low to result in an important reduction in the spread or concentration of TB droplet

nuclei. However, if the units are to be used, the hospital should develop and implement written filter change criteria for the RTU systems and the portable HEPA filters in the MEC. These criteria should include change frequency, necessary safeguards to be followed by maintenance personnel (gloves, respirators), and proper disposal methods. Filters should be treated as potentially contaminated with microorganisms. Hospital personnel should be trained regarding these procedures. Some HEPA filters are designed with a built-in bag to provide an easy disposal mechanism for contaminated filters. The manufacturer of the HEPA units should be consulted regarding this item.

6. A minimum of 25 CFM of outside air per patient should be provided for each patient room. The ability of a room to maintain negative pressure should be re-evaluated whenever changes in air supply volumes are made.

7. GMH should consider installing HEPA-filtered booths and/or scavenging tents in the Infectious Diseases Clinic.

VIII. FUTURE ACTIVITIES

NIOSH investigators are planning to conduct an epidemiologic study to determine the TB conversion rates and potential risk of TB infection among various groups of hospital employees. The first step will be to identify the areas of the hospital with potential sources of TB exposure (patients with positive TB cultures) over the past 3 years. This information will help to define which hospital areas and job categories should be included in the epidemiologic investigation. The next step in the investigation will be to obtain additional hospital records pertinent to the study. These records will include information concerning the results of employee TB skin testing and history of workplace assignments. Identified areas and workers will then be evaluated, in conjunction with NIOSH industrial hygienists, to develop recommendations aimed at reducing the risk of TB transmission among GMH employees.

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APPENDIX B

DEPARTMENT OF HEALTH & HUMAN SERVICES | Public Health Service, Region IV

National Institute for Occupational Safety and Health

Division of Preventive Health Service
Suite 1105
101 Marietta Tower
Atlanta, Georgia 30323
404/331-2396

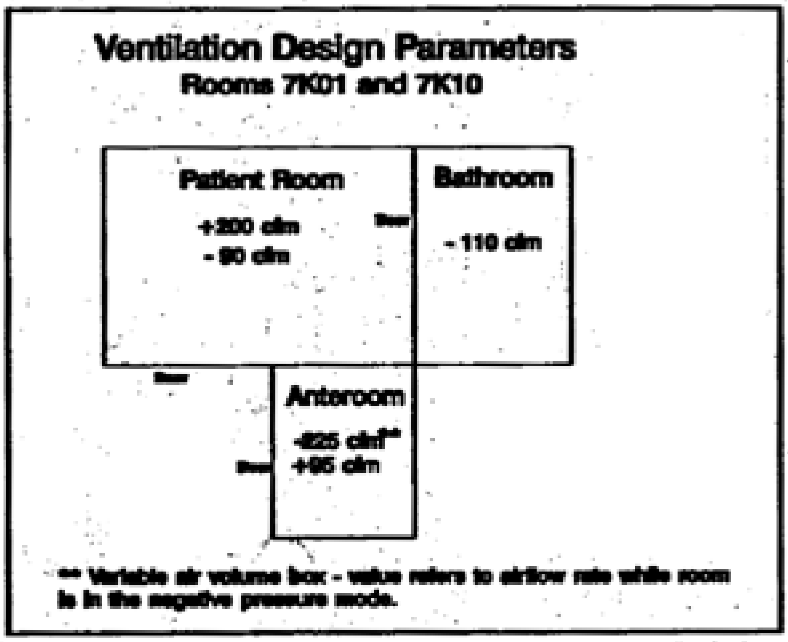
January 3, 1994

Ms. Pat Moore
Nurse Epidemiologist
Epidemiology Department, Room E-405
Grady Hospital
P.O. Box 26001
Atlanta, Georgia 30335

Dear Ms. Moore:

On Wednesday, December 29, 1993, we conducted smoke tests on six "negative pressure" rooms and two isolation rooms in the new tower at Grady Hospital. The Grady engineering staff created the "negative pressure" rooms (7J02, 7J03, 7J14, 7J15, 5J06, 5J11) by blocking the supply air into the rooms. It was not confirmed that the exhaust air from these rooms is vented to the outside. A portable high efficiency particulate air (HEPA) filtration unit was placed inside each modified room by Grady engineers. These rooms are serving as temporary isolation rooms until permanent modifications can be implemented by the hospital.

The two isolation rooms in neurosurgical ICU (7K01, 7K10) were originally designed as isolation rooms according to the ventilation plans. All air from the two rooms is exhausted to the outside, and both rooms have anterooms. A switch on the wall purportedly can be used to change the room from negative to neutral or positive pressure. The figure below indicates the design airflow rates for both rooms. The negative numbers indicate the exhaust air flow rate in cubic feet per minute (CFM), while the positive numbers indicate supply air flow rate.



Methods

To check the rooms for negative pressure, the smoke tube was held parallel to the door and smoke was issued from the tube slowly to assure that the velocity of the smoke did not overpower the air velocity. This procedure was performed at the top, middle, and bottom of the closed door. If smoke traveled into the room at all three door locations, the room was designated to be under negative pressure. If the smoke was blown outward at any door location, the room was deemed to be under positive pressure.

Evaluation Criteria

The American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE) and the American Institute of Architects (AIA) have guidelines for various ventilation parameters in hospitals.[1,2,3] A comprehensive discussion of these guidelines can be found in a May 1992 interim report to Grady Hospital.

Recommended ventilation rates in hospitals are frequently expressed in terms of air changes per hour (ACH). An ACH is defined as the theoretical number of times that the air volume of a given space will be replaced in a one-hour period by air supplied to the space or transferred to the space from adjacent spaces. However, the terminology is misleading; air is not actually "changed" the theoretical number of times per hour, even if there is perfect mixing.

For isolation rooms, ASHRAE recommends a minimum of six ACH with two of the six ACH being outside air. All air should be exhausted directly to the outside, and the room should be maintained under negative (lower) pressure with respect to adjacent areas. Negative pressure is attained by exhausting more air from an area than is being supplied. According to draft guidelines issued by the Centers for Disease Control and Prevention, negative pressure can be achieved by balancing the room supply and exhaust flows to set the exhaust flow to a value 10% (but no less than 50 cfm greater than the supply) greater than the supply.[4] The draft also states that a pressure differential of 0.001 inch of water and an inward air velocity of 100 feet per minute are minimum acceptable levels.

Results

Four of the six "negative pressure" rooms were actually under positive pressure (see table next page). Several nurses commented that the rooms were unusually warm, and some patients were opening the windows. The smoke tests were conducted after closing the windows.

One isolation room (7K10) was under positive pressure. The switches to change the rooms from negative to positive pressure did not appear functional, since no changes in pressure were observed regardless of the setting.

Room Number	Pressure
7J02	Negative
7J03	Negative
7J14	Positive
7J15	Positive
5J06	Positive
5J11	Positive
7K01 **	Negative
7K10 **	Positive

** These rooms were designed as isolation rooms.

Discussion and Recommendations

Grady Hospital should re-assess their program of creating "negative pressure" rooms in the new tower. If negative pressure and thermal comfort cannot be maintained in these rooms, it is unlikely that these rooms will be useful to the hospital, even as a temporary measure. If any air from the rooms is recirculated into the general ventilation system, it is is unacceptable for these rooms be used for isolation. The effectiveness of portable filtration units has not been adequately evaluated, and there is likely to be considerable variation in the effectiveness of these devices.[4] Therefore, it should not be assumed that these units will adequately filter the air of tuberculosis organisms.

Blocking the supply air in the ventilation system will disrupt airflow to other areas served by the same ventilation system. It is possible that isolation room 7K10 was made positive as the result of changes in other areas of the ventilation system.

According to the ventilation plans, the pressure in the isolation rooms is controlled by varying the amount of exhaust in the anterooms. The patient room becomes negative to the hallway when the anteroom is negative with respect to the patient room and the hallway. It should be noted that the anteroom cannot be considered a "semi-clean" area, since contaminants from the patient room will migrate into the anteroom. Therefore, hospital workers should don their respirator before entering the anteroom.

If you have any questions, please feel free to telephone me at (404) 331-2396.

Sincerely yours,

John A. Decker
Industrial Hygienist

cc:
A. Miller (NIOSH)
H. Blumberg (Grady Hospital)
J. McGowan (Grady Hospital)

<u>References</u>

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APPENDIX C

DEPARTMENT OF HEALTH & HUMAN SERVICES

National Institute for Occupational Safety and Health

Public Health Service, Region IV

Suite 1106
101 Marietta Tower
Atlanta, Georgia 30323
404/331-2396

August 25, 1994
HETA- 92-232

Ms. Pat Moore
Nurse Epidemiologist
Epidemiology Department
Grady Hospital
P.O. Box 26001

Dear Ms. Moore:

On August 9, 1994, we conducted a tracer-gas ventilation study of two isolation rooms at Grady Hospital. The tracer-gas was used to determine room air change rates and the potential for contaminants to migrate from the rooms.

A new isolation room on the fourth floor (4B-20) and an older "fan" room on tenth floor (10D-32) were evaluated. Room 4B-20 featured an anteroom and 100% exhaust of room air to the outside. Room 10D-32 was a regular patient room having a window-mounted axial fan blowing air out the window to maintain the room under negative pressure. Room 10D-32 also had a "recirculating thermal unit" or RTU, which contained a recirculation fan, filter, and cooling coils for treating the combined supply and return air. The unit introduced some outside air from the hospital's ventilation system.

Methods

The tracer-gas evaluation was conducted according to the American Society for Testing and Materials (ASTM) Standard E741-93, "Standard Test Methods for Determining Air Change in a Single Zone by Means of a Tracer Gas Dilution," using sulfur hexafluoride (SF_6) tracer gas.[1] The concentration-decay test method, described in the ASTM Standard, was used. The air change rate was determined by measuring the logarithmic rate of decline in SF_6 concentration. This method assumes the tracer gas follows a first-order exponential-decline in concentration. The specific procedures are discussed later in this section.

The NIOSH Recommended Exposure Limit (REL) for SF_6 is 1000 ppm, expressed as a 10-hour time-weighed average.[2] SF_6 is considered pharmacologically and toxicologically inert.[3] At high concentrations, SF_6 is a simple asphyxiant. The source SF_6 for this project was 1 % SF_6 in nitrogen (Matheson Gas Products, Morrow GA), released from a compressed gas cylinder using a regulator. NIOSH Human Subjects Review Committee approval is not required for the use of SF_6. Although the concentration of SF_6 in this study was less than 8 ppm, unoccupied rooms were chosen to minimize potential disruption to staff and patients.

Measurement of SF_6 was accomplished with a Brüel & Kjær Type 1302 direct-reading multi-gas monitor. The principle of detection is infrared absorption at a specific wavelength with subsequent analysis via the photoacoustic effect. The concentration range for the instrument was approximately 0.050 to 600 parts per million (ppm) SF_6.

SF_6 was released into the isolation room at approximately 2 liters per minute (Lpm). The SF_6 concentration was monitored continuously (approximately every 45 seconds), and a fan was used to ensure uniform mixing throughout the room. When the concentration reached 6-7 ppm., the gas was turned off, the fan was turned off, and the time was recorded. The concentration-decay was then measured inside the room (over the bed) until the concentration dropped between 1/8 to 1/10 the original room concentration. A peak concentration of 6-7 ppm was used rather am 2-3 ppm as originally planned due to the limit of detection of the Brüel & Kjær monitor for SF_6. The fan was turned off during the concentration-decay phase of the evaluation.

A NIOSH investigator located outside the room collected air samples in air-sampling bags 5 minutes, 15 minutes, and 20-30 minutes following initial release of the SF_6 gas. The air-sampling bags were filled using Gillian high-flow battery-powered air pumps. Following completion of the concentration-decay measurements, the concentrations of SF6 in the sample bags were measured.

The natural log of SF_6 concentration versus elapsed time was graphed, yielding a straight line plot. The air change rate is equal to the slope of the line.[4] Since the elapsed time was plotted in terms of minutes, the slope was multiplied by 60 to convert "air changes per minute" to "air changes per hour."

For comparison purposes, supply and exhaust airflow for room 4B-20 was measured with a Shortridge Instruments Airflow Hood. Room pressurization was determined with a smoke tube, and room volume was determined by actual measurements. From this information, the air change rate for the room was calculated. For room 10D-32, the configuration of the RTU and axial fan did not allow ventilation measurements or calculation of the air change rate. However, pressurization of the room was evaluated with a smoke tube.

During the evaluation, the doors to the isolation rooms were closed at all times. However, we were also interested in evaluating the potential for contaminants to migrate from a properly functioning isolation room if the room doors were left open. After completing the initial evaluation of room 4B-20, SF_6 gas was released inside the room while the doors were left open for approximately 5 minutes. During this time, a NIOSH investigator walked in and out of the room continuously. Another NIOSH investigator measured the SF_6 concentration outside the room, near the nurses station.

To check the rooms for negative pressure, the smoke tube was held parallel to the door and smoke was discharged from the tube slowly to assure that the velocity of the smoke did not overpower the air velocity. This procedure was performed at the top, middle, and bottom of the closed door. If smoke traveled into the room at all three door locations, the room was designated to be under negative pressure. If the smoke was blown outward or stayed stationary at any door location, the room was deemed to be under positive pressure.

Evaluation Criteria

The American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE) and the American Institute of Architects (AIA) have guidelines for various ventilation parameters in hospitals.[5,6,7] A comprehensive discussion of these guidelines can be found in a May 1992 interim report to Grady Hospital.

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Results and Discussion

Figure 1 shows the concentration-decay plot for room 4B-20. The tracer-gas method indicated the ventilation system provided approximately 19.5 ACH, well in excess of the minimum recommended 6 ACH. The air-change rate calculated from ventilation measurements (using an air flow hood) and room dimensions indicated approximately 18.3 ACH. Since the volume of objects in the room were not subtracted from the room volume, it was expected that the ventilation-measurement method would yield a slightly lower (and less accurate) estimate of air change rate compared to the tracer-gas method.

In addition to air-change rate, the tracer-gas method provided some infon-nation on air mixing in the room. The logarithmic concentration-decay plot yielded a straight line, suggesting good air mixing at the location where SF6 concentration was measured (over the bed).' Because the air change rate calculated from ventilation measurements was similar to that calculated from tracer-gas decay, it can be inferred that air mixing throughout the entire room, on average, was good.

Figure 2 shows the concentration-decay plot for room 10D-32. The air-change rate, as estimated by the tracer-gas method, showed approximately 4.9 ACH, less than the minimum recommended 6 ACH. Nonetheless, the logarithmic concentration versus time plot yielded a straight line, also suggesting good air mixing in the area over the bed. Direct ventilation measurements were not conducted in this room. The low air exchange rate, which is probably typical of other "fan" rooms at Grady, demonstrates one of the inadequacies of this type of isolation room.

No SF6 was detected outside either room as long as the doors were closed. This finding was consistent with the smoke tests, which indicated both isolation rooms were under negative pressure. When the doors to room 4B-20 were opened, SF_6 was detected at the nursing station within 5 minutes, despite smoke tests showing the room was under negative pressure. This finding indicates the importance of keeping the doors to isolation rooms closed. The open-door SF_6 test was not conducted on room 10D-32.

If you have any questions regarding our evaluation or this report, feel free to telephone me at (404) 331-2396.

Sincerely yours,

John A. Decker

John A. Decker, M.S
Industrial Hygienist

Enclosure
cc:
Henry Blumberg, Grady
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Katherine Cox, AFSCME

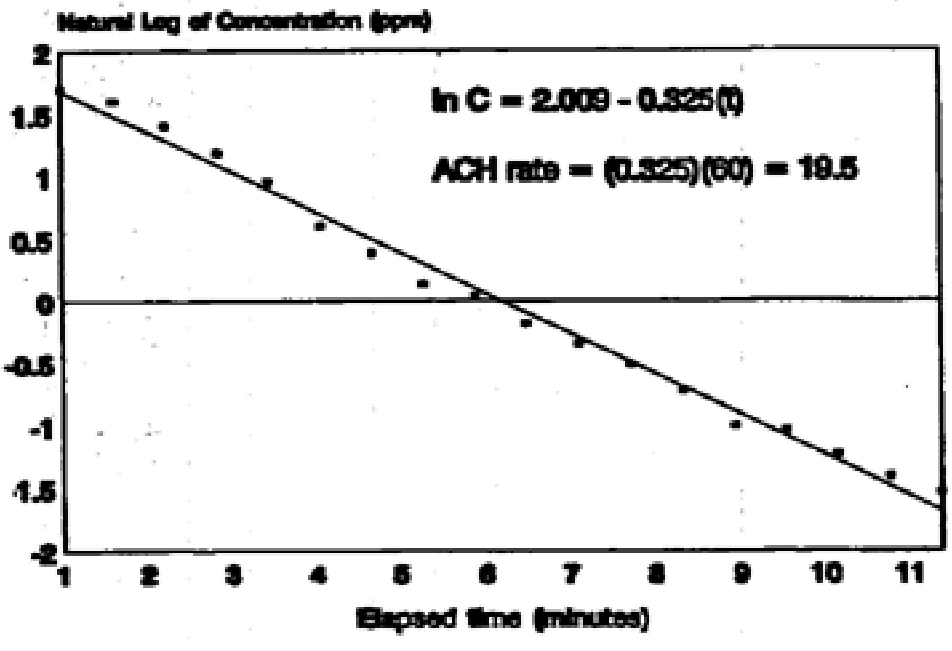
Figure 1

Grady Hospital, HETA 92-232

Sulfur Hexafluoride Decay

Grady Hospital
Room 4B 20

August 9, 1994



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