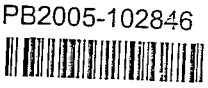

TECHNICAL REPORT:

Final Performance Report

for

PROJECT TITLE: Health Care Worker Compliance with Hepatitis B Vaccine

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TABLE OF CONTENTS

LIST OF ABBREVIATIONS

American Hospital Association	AHA
Accreditation Council on Graduate Medical Education	ACGME
American Medical Association	AMA
Bloodborne Pathogens Rule	BPR
Centers for Disease Control and Prevention	CDC
Degrees of freedom	DF
Health care workers	HCWs
Hepatitis B virus	HBV
Interscience Conference on Antimicrobial Agents and Chemotherapy Meeting	ICAAC
Institutional vaccination rates	IVR
Iowa Statewide Surveillance System	ISSS
Joint Commission on Accreditation of Healthcare Organizations	JCAHO
Laboratory workers	LWs
National Surveillance System for Hospital Healthcare Workers	NaSH
Nursing assistants	NAs
OSHA's Bloodborne Pathogens Rule	BPR
Occupational Safety and Health Administration	OSHA
Purified protein derivative	PPD
Registered Nurses	RNs
Society for Healthcare Epidemiology of America	SHEA
Standard Metropolitan Statistical Area	SMSA
Standard precautions	SP
Universal precautions	UP

LIST OF FIGURES Page

LIST OF TABLES Page

SIGNIFICANT FINDINGS

The studies supported by this grant have advanced the understanding of factors influencing the delivery of hepatitis B vaccine (HBV) to health care workers in community health care facilities. Institutional levels of HBV vaccine protection among all occupational groups at risk in Iowa hospitals have significantly increased since the publication of the Occupational Health and Safety Administration's (OSHA's) Bloodborne Pathogens Rule (BPR).(1) Importantly, these studies demonstrate that both institutional-level variables, as well as worker-level variables, are important in health care workers' acceptance of the HBV vaccine. Additionally, these studies suggest that modifiable aspects of institutional occupational health programs may increase the effectiveness of immunization programs for hospital-based workers.

Data from this research demonstrate that in early 1992, prior to when OSHA's BPR became enforceable in July 1992, institutional levels of vaccine acceptance in Iowa hospitals were related primarily to three factors: composition of the workforce, management support, and requirement of vaccine receipt for employment. Management support was an important determinant, both in terms of the active encouragement of vaccination by clinical leaders, particularly by the chief of staff, and the personal receipt of HBV vaccination by leaders themselves.

The document "Healthy People 2000: National Health Promotion and Disease Prevention Objectives" identified a goal of reaching institutional levels of 90% or more workers vaccinated against HBV of those at risk in health care facilities.(2) This target was operationalized for this research as an institutional measure of program effectiveness for community hospital worker HBV vaccination programs. Whereas a number of health care facilities have achieved these levels of vaccination against HBV among certain occupational groups at risk, the majority of facilities have not been able to protect all groups at risk. In this study, levels of vaccination in Iowa and Virginia health care facilities were highest among laboratory workers and lowest among physicians and housekeepers. The most important factors associated with achievement of this target rate of vaccine acceptance within workers overall within Iowa institutions included: the baseline institutional vaccination rate, location in a rural area, and active encouragement by clinical leaders.

Separate logistic regression models were developed to identify institutional organizational and program factors associated with achievement of this level of HBV vaccination within different occupational groups of workers in all participating hospitals (N = 190) in Iowa and Virginia. Characteristics of effective hospital programs to vaccinate registered nurses included those with fewer outpatient visits, use of an invitation letter to offer the vaccine, a reminder letter to complete the series, and receipt of HBV vaccination by clinical leaders. Factors independently associated with achievement of the target rate among other nursing personnel included: provision of vaccine at the worksite, active encouragement of vaccination by the clinical leaders, receipt of the vaccine by clinical leaders, and ongoing standard precautions compliance monitoring by coworkers and others. The model predicting facilities achieving the target rate among laboratory workers identified similar factors: provision of vaccine at the worksite, ongoing standard precautions compliance monitoring, and lower levels of facility complexity.

Worker level data also demonstrate that the determinants of HBV vaccine acceptance vary among different occupational groups of health care workers. Putative reasons for health care workers to either receive or refuse the hepatitis B vaccine were examined using factor analysis. Identified factors among those receiving one or more dose of the vaccine included:

social influence (recommendation of physicians, supervisors, role models, friends and spouse) and knowledge of the disease and vaccine. In contrast, refusal was primarily related to concern about vaccine side effects and problems with vaccine access. Separate logistic regression models were developed and validated to identify independent predictors of initiating (1 or more doses) or completing (3 or more doses) the vaccine series. Independent predictors of initiating the series included younger age, occupation, increased blood exposure frequency, and increased frequency of recent influenza vaccination. Occupation (increased acceptance among housestaff, nurses, nursing assistants, laboratory technicians), increased frequency of blood exposure, and recent influenza vaccination were also predictors of series completion.

USEFULNESS OF FINDINGS

These data demonstrate the importance of management commitment and support of an occupational health program within community health care facilities to protect workers through vaccination from a major work-related hazard, such as hepatitis B infection. They suggest that interventions targeted at management within health care institutions may be a particularly effective approach to impacting the health and safety of workers.

Knowledge of health care level factors such as occupation, blood exposure frequency and acceptance of other preventive services may help identify health care worker groups with low vaccine acceptance most likely to benefit from targeted vaccine delivery. Hepatitis B vaccine should be offered routinely during evaluation for occupational blood exposure. Future vaccine implementation efforts should emphasize the involvement of physicians and supervisors and education about occupational disease risk, as well as the reliability and safety of the vaccine.

Institutional level program factors that may be particularly effective include the use of an invitation letter to initially offer the vaccine, a reminder letter to complete the series, and provision of vaccine at the worksite. These studies demonstrate that it is important to obtain the active involvement and support of clinical and opinion leaders within the institution in the vaccine delivery program. Additionally, ongoing monitoring of standard precautions (SP) compliance by coworkers and others appears to be an important marker of an effective institutional occupational health program for health care workers.

This project also identified a number of areas of needed improvement within health care facility occupational health programs. Many health care facilities have only rudimentary surveillance programs to identify clusters or an increased incidence of occupational exposure, illnesses or injuries. Improved electronic databases are needed within health care facilities to allow the ready retrieval of data related to preventive health measures delivered and the occupational exposures of health care workers. Only through active prospective surveillance using standard definitions of outcomes and exposures is it likely that health care institutions will be able to identify potential problem areas and optimally protect their workers. The Centers for Disease Control and Prevention (CDC) has begun to address this need through its development and pilot testing of the National Surveillance System for Hospital Healthcare Workers (NaSH). However, in this era of increased development of health care systems, rapid penetration of managed care into most markets, and the rapid reorganization and downsizing of community hospitals, the occupational health program within many facilities should be considered particularly at risk. Finally, as with many other occupational health programs, further study is needed to determine how best to implement vaccine delivery to workers within health care institutions, and how to optimally protect them from occupational exposure to infectious pathogens.

ABSTRACT

The overall goal of this project was to evaluate the distribution and determinants of hepatitis B vaccine use and compliance in community hospitals and health care facilities and among health care workers. This study was designed to identify institutional, occupational and behavioral variables among health care workers that impact their practice of effective preventive health measures, using receipt of the hepatitis B virus (HBV) vaccine as the paradigm.

The health care facilities studied include the hospitals and chronic care facilities in Iowa in the Iowa Statewide Surveillance System (ISSS) and hospitals in Virginia. Two cross-sectional surveys of Iowa health care institutions were performed at baseline in early 1992 and 2.5 years later to define the rates and distribution of hepatitis B vaccine compliance prior to and following the implementation of OSHA's Bloodborne Pathogens Rule. A total of 141 ISSS facilities (94% participation) were surveyed just after OSHA's Draft Bloodborne Pathogens Rule (BPR) was published to determine mean institutional vaccination rates (IVR) in different occupational groups at baseline. Institutional HBV vaccine delivery program characteristics were categorized according to survey responses of infection control and occupational health personnel at the selected facilities. Data from the American Hospital Association's (AHA) Guide were incorporated to assess community and institutional health care organizational characteristics. Subsequently, data were collected from the same sample of facilities to evaluate changes in programs, institutional vaccination rates and examine the effect of OSHA's mandate. Additionally, identical data were collected from a sample of unstudied hospitals in Virginia. Multivariate statistical models were developed to identify organizational and program characteristics of effective vaccine delivery programs.

A random sample of 1018 health care workers at risk of occupational exposure to blood and body fluids, stratified by occupation, were surveyed to identify factors independently related to HBV vaccine refusal or acceptance. Multivariate statistical models were developed and validated to identify occupational and behavioral characteristics associated with initiation or completion of the vaccine series.

Vaccine implementation programs differed in terms of measured program characteristics by size of the institution and location (urban versus a rural county). Multiple linear regression analysis was used to identify factors associated with the institutional vaccination rate (IVR) at baseline in Iowa health care facilities. Several variables, including active encouragement and participation in vaccination by clinical leaders, the proportion of registered nurses in the workforce, and a requirement that employees receive the HBV vaccine for employment were independently associated with the IVR. The frequency of educational programs regarding HBV was of borderline significance.

A multivariate linear regression model was developed to identify institutional and program factors associated with the IVR in Iowa facilities at follow-up. This model demonstrated the importance of workforce related factors (proportion of registered nurses, change in the proportion of laboratory workers), as well as program factors (provision of the vaccine at the worksite and at meetings, and the baseline rate of vaccination within the institution) in influencing the HBV IVR.

A multiple logistic regression model was developed to identify the most important factors associated with achievement of a target summary rate of HBV vaccine acceptance of 90% or greater among all workers. Those factors independently related to the summary IVR included:

the baseline vaccination rate within the institution, location in a rural area, and active encouragement of vaccination by the nursing director.

At the individual worker level, HBV vaccine receipt was strongly related to social influence (physicians, supervisors, role models, friends and spouse) although perceived risks and knowledge of the disease were also important. Among those workers remaining unvaccinated, concern about side effects of the vaccine, knowledge of the disease and their own risk, and access to the vaccine were the major factors identified.

Fifty-four percent (482 of 898) of previously non-immune workers had completed the series, while 70% (626) had received one or more doses. The most important independent predictors of HBV vaccination among individual health care workers included occupation, frequency of mucocutaneous blood exposure, prior influenza vaccination, and age. Independent predictors of initiating the vaccine series included younger age (OR = 0.98 per year, CI_{95} = 0.96-0.997), occupation (housestaff OR = 2.9, CI_{95} = 1.1-7.9 and nurses OR=2.1, CI_{95} = 1.0-4.3 versus housekeepers), increased blood exposure frequency (OR = 2.4, CI_{95} = 1.6-3.5 for 1-6 vs. 0 exposures in past year), and increased frequency of recent influenza vaccination (OR = 3.3, CI_{95} = 2.0-5.3 for 1 vs. 0 doses in prior 3 years). Occupation (increased acceptance among housestaff, nurses, nursing assistants, laboratory technicians), increased frequency of blood exposure, and recent influenza vaccination were also independent predictors of HBV vaccine series completion.

BODY OF REPORT

Background

Hepatitis B is one of the most important causes of chronic viral infection worldwide.(3) In the United States, the reported rate of hepatitis B has declined by over half since 1987, presumably due to improved blood-screening procedures, the availability of virus inactivated blood components, increased use of isolation materials and standard precautions, and due to vaccination programs.(4) However, transmission of hepatitis B in the health care setting continues to occur.(5)

Hepatitis B infection remains a major cause of occupational disease among health care workers,(6-9) and occasionally of transmission from an infected health care provider to patients.(10) The incidence of new definite HBV infections is 1.0% per year among susceptible health care workers with frequent blood contact versus none in those with limited blood contact.(11) Frequency, rather than duration of exposure to blood, appears to be the most important factor in the development of occupational HBV infection.(11) Hepatitis B vaccination is a routinely recommended measure to protect health care workers from occupational infection.(12-14) It has become well accepted that health care institutions have a responsibility to vaccinate their workers against HBV.(15) However, implementation of immunization programs for health care workers have differed widely.(16)

Despite the frequency of the infection in hemodialysis centers, only 20% of patients and 58% of dialysis staff responding to the most recent national survey had measurable protective antibody.(17) In a study of British general practitioners, only 48% had begun or completed the series, even though the majority (88%) believed that they should be vaccinated.(18) Similarly, only 25% of nurses and 49% of physicians in another survey had been vaccinated.(19)

Health care worker acceptance of the hepatitis B vaccine in most studies has ranged from 25-50%.(18-22) Up to three-fourths of hospital workers in certain clinical settings or

endemic areas have received the vaccine.(23-26) However, up to one-half of North American surgeons currently remain unprotected.(27) Low rates of vaccine acceptance are difficult to comprehend, given the availability of a safe, effective vaccine since 1981.(28-32) Given changes in the epidemiology of hepatitis B infection in the U.S., it has been suggested that changes are needed in vaccination strategies for the disease.(33; 34)

Although a level of 90% hepatitis B vaccination among health care workers has been identified as an important public health goal,(2) it is unclear whether and exactly how that target may actually be achieved. The Occupational Safety and Health Administration (OSHA) published the Draft Bloodborne Pathogens Rule (BPR) in December 1991, which became enforceable in July 1992, mandating education about the vaccine, bloodborne pathogens training and offering the HBV vaccine to all workers occupationally-exposed to blood.(1)

The determinants of HBV vaccine use among U.S. health care providers are not well understood. Various reasons have been suggested for health care workers' failure to receive the HBV vaccine, including fear of side effects, availability and cost.(18; 23; 24; 35-37) Most published work to date studying HBV vaccine delivery to health care workers has been descriptive and involved single institutions. However, the determinants of HBV vaccine acceptance are likely to be complex. These determinants are likely to change over time as data have accumulated regarding the safety of the vaccine. Changes in health care regulations, organizational factors and management influences are likely to affect these determinants. Importantly, multivariate statistical techniques have been used infrequently to examine the determinants of HBV vaccine acceptance among health care workers or within a range of institutions.

Health care institutions utilize markedly different occupational health programs, particularly approaches to HBV vaccination implementation. Differences in these approaches were hypothesized to be directly related to the effectiveness of a given vaccination program. The investigators hypothesized that determinants of institutional hepatitis B vaccine compliance rates included role model behavior, access to vaccination, characteristics of the bloodborne pathogens educational program, and implementation of OSHA's BPR. Individual health care worker vaccination was hypothesized to be related to age, occupation, sharps exposure, exposure to blood, experience with hepatitis B, and personal attitudes and beliefs. Further, it was hypothesized that universal (now standard) precautions training and vaccine implementation mandated by OSHA could indirectly increase the effectiveness of other aspects of the occupational health program within a facility.

The overall goal of this study was to begin to characterize the effects of selected institutional and individual determinants of HBV vaccine acceptance in order to facilitate provision of the vaccine. This project examined individual health care worker factors, as well as institutional factors which were thought both to be important in the individual's decision to be vaccinated and to use other protective health measures. The long-range goal of the project was to potentially help prevent HBV infection and disease among health care workers and their patients.

Specific Aims

The following specific aims were addressed by this study:

1. To compare the relative efficacy of different vaccine implementation approaches, and to identify the most effective programs in different institutional settings;

2. To categorize levels of compliance with OSHA's Bloodborne Pathogens Rule and determine their effect on vaccine compliance and the frequency of occupational exposures to blood, sharps and tuberculosis;
3. To determine the effect of repeated educational programs on vaccine compliance;
4. To evaluate the relative importance of institutional organizational and program factors in determining levels of hepatitis B vaccine acceptance among workers;
5. To determine whether institutional levels of compliance with standard precautions is related to institutional rates of HBV vaccination;
6. To examine the importance of individual predictors of the acceptance of hepatitis B vaccine by workers.

Hypotheses:

Prior to data collection, we hypothesized that institutional occupational health programs varied in terms of their approaches to HBV vaccine delivery. Further, we proposed that certain characteristics of these different programs would be responsible for more effective vaccine delivery and thus be related to higher institutional vaccination rates. The components of the institutional vaccine delivery program that we hypothesized to be most likely related to effectiveness included: involvement and support of clinical leaders, access to the vaccine, and specific program components, such as follow-up. We expected that factors such as the type of educational program, and experience with patients with hepatitis B would be relatively unimportant.

Further, we hypothesized that facility organizational characteristics, such as the size of the facility, payroll, and institutional complexity in terms of services provided at a facility would be directly related to the IVR at the facility. In particular, we hypothesized that larger facilities in metropolitan areas would have higher rates of HBV immunization among their workers than in smaller, rural facilities. We also expected that there would be little or no difference between programs in Iowa and Virginia.

We assumed that implementation of OSHA's BPR would be associated with a significant improvement in the levels of HBV vaccine acceptance among facilities. It was hypothesized that variation in the implementation of each of the components of the BPR would be associated with differences in the IVR when reassessed several years later. Further, we hypothesized that compliance with aspects of the BPR directly related to HBV vaccine delivery, particularly offering the vaccine to all workers and obtaining signed declination waivers of the vaccine, would be particularly effective components.

The following specific hypotheses were developed:

1.A. Institutional occupational health programs vary in terms of their approaches to hepatitis B vaccine delivery;

1.B. Characteristics of these programs, particularly involvement and support of clinical leaders, access to the vaccine, and specific program components, such as follow-up are associated with higher rates of hepatitis B vaccine acceptance in health care facilities.

2. High levels of compliance with OSHA's Bloodborne Pathogens Rule is directly related to levels of hepatitis B vaccine acceptance among workers;

3. Repeated educational programs have relatively little effect on vaccine acceptance;

4. Program factors are relatively more important than institutional organizational characteristics in determining levels of hepatitis B vaccine acceptance among workers;

5. Institutional levels of compliance with universal precautions are unrelated to institutional rates of HBV vaccination;

6. Individual workers who are younger, have more exposure to blood and body fluids, and more often directly handle sharps devices will have higher rates of acceptance of hepatitis B vaccine than other workers without these factors.

Procedures and Methodology

The overall goal of this study was to evaluate the distribution and determinants of hepatitis B (HBV) vaccine use and acceptance in Iowa hospitals and among Iowa health care workers. The overall study design involved cross-sectional institutional surveys in Iowa at baseline and 2.5 years later, surveys of Virginia health care facilities, and individual worker surveys (Table 1). The health care facilities studied include the hospitals and the largest chronic care facilities in Iowa in the Iowa Statewide Surveillance System (ISSS). Health care facilities in the ISSS are represented by trained infection control practitioners (ICPs) who perform ongoing surveillance at their facilities and participate in statewide biannual meetings and continuing education in infection control and occupational illnesses of health care workers.

A total of 141 ISSS facilities were surveyed in early 1992 prior to OSHA's Bloodborne Pathogens Rule (BPR) becoming enforceable to determine mean institutional vaccination rates (IVR) in different occupational groups. Data from the same institutions were collected again two and one-half years after the initial survey. This survey was timed to provide an assessment of the effect of the implementation and enforcement of OSHA's BPR Rule on the same institutions. A third sample of ICPs at hospitals in Virginia were surveyed with the same instrument in 1995 in order to allow assessments within different occupational groups, make geographic and health system comparisons, as well as to provide a sample to confirm the results obtained from facilities in Iowa.

Finally, a stratified random sample of 1018 health care workers at risk for occupational blood exposure at a university hospital were surveyed via a mail-out survey. Potential reasons for vaccine acceptance or refusal were evaluated with factor analysis. Logistic regression models were calibrated on a stratified random subsample to identify independent predictors of initiating and completing the series, then validated on the remaining subjects.

Baseline Institutional Study:

A questionnaire regarding institutional and program characteristics was developed based on the published scientific literature and interviews with health care workers, health care managers, infection control practitioners and other experts at different institutions. An additional instrument was developed to assess compliance with specific aspects of OSHA's Bloodborne Pathogens Rule. The instruments used are described below.

The draft instrument was pretested in a sample of experienced infection control practitioners, and revised based on their input. The final questionnaire was sent to infection control practitioners at the 141 hospitals and largest chronic care facilities in the existing Iowa Statewide Surveillance System. A cover letter accompanied the survey and letter from the Director of the Iowa Department of Public Health, Mr. Christopher Atchison, requesting participation. Two additional mailings of a cover letter and the survey instrument were sent to non-responding subjects at approximately one-month intervals. Individuals failing to respond to the third request or those providing incomplete or contradictory data were contacted by telephone to complete the questionnaire.

The institutional spectrum of methods of vaccine implementation (specific aim 1), compliance with the components of the Bloodborne Pathogens Rule (specific aim 2), as well as the number of times each approach was used (e.g., effect of repeated educational interventions, specific aim 3), was requested from each institution. Repeated institutional assessments in the hospitals in the Statewide System were performed approximately 30 months after the initial survey to identify any changes in the vaccine implementation programs at a given institution in response to OSHA's mandate. Programs were classified into categories of responsiveness based upon the number of changes made in the vaccine implementation program compared to the program characteristics at baseline. This categorization was performed in relation to the changes made by all other programs in the given institution's category (acute hospital versus chronic care facility).

This longitudinal study design was performed to allow identification of institutions with significant increases in the rates of health care worker vaccination, presumably representing those health care facilities with effective vaccine implementation programs. Linear and logistic regression were performed to develop multivariate models to identify variables associated with institutional HBV vaccination rates.

Follow-up Institutional Study:

A second "follow-up" survey was performed to provide an assessment of the effect of the implementation and enforcement of OSHA's BPR on the same institutions. The same institutions in the ISSS were surveyed again in late 1994 and early 1995, approximately two and one-half years after the initial survey. The survey used was similar to the original baseline survey, with a few modifications, based on the experience with the baseline survey. Three facilities either had merged or had closed in the interval, leaving a denominator of 138. Thus, 138 institutions were contacted in this second survey. The same survey methods were used that had been previously employed in the baseline survey.

Validation Study:

A third survey of hospitals in Virginia was performed in 1995 to determine whether there were important geographical or system differences in institutional HBV vaccine delivery programs and expand the sample size of institutional data. This survey included cover letters of support from Dr. Barry Farr, Hospital Epidemiologist at the University of Virginia, and Dr.

Richard Wenzel, formerly Hospital Epidemiologist at the University of Virginia.(38) The same institutional questionnaire used in the study of Iowa health care facilities described earlier was sent to infection control practitioners at hospitals in Virginia for completion.

Two repeat mailings of the institutional survey were performed as previously described for the Iowa facilities. Institutions not returning the validation questionnaire were contacted by telephone to complete the questionnaire.

Health Care Worker Study:

The objectives of the health care worker study were to test the statistical associations between putative determinants of vaccine acceptance and actual vaccination, as well as to model the independent associations between the study variables and vaccine acceptance. The University of Iowa Hospitals and Clinics (UIHC) is a 900 bed referral hospital located in a community of approximately 60,000 inhabitants, with an additional 40,000 persons located in the surrounding county. The UIHC is the only tertiary referral hospital in the state and serves Iowa, eastern Illinois, and the surrounding region. It is affiliated with the University of Iowa, a state university with approximately 27,000 students, and 11,200 faculty and staff. The HBV vaccine has been provided at no cost to occupationally-exposed employees at the medical center in the employee health clinic since it first became available. The vaccine has been offered at the initial employment visit, during evaluation for occupational injury, and at request. However, concentrated efforts to increase compliance with the vaccine had not been implemented prior to the current study.

Data Sources:

Institutional Questionnaires:

Vaccine program characteristics of potential interest (Table 2) explored in the questionnaire included: clinical leader involvement, educational program, access to the vaccine, provision at the work site and departmental meetings, leadership support, employment requirement, vaccination follow-up, serologic response approach and availability of vaccination records, e.g., whether records are computerized. The protocols in place for management of sharps injuries and blood exposures were also considered as potentially important aspects, since the vaccine is often given during evaluation for percutaneous injury. Other items that were included to assess for evidence of an exposure relationship between frequency and effectiveness were the frequency of periodic review of employee vaccination status, the frequency of periodic reminders to be vaccinated, and the frequency of continuing education programs on HBV vaccination. The role of management commitment for the program was assessed through items addressing the involvement of clinical leaders in the program, their active encouragement of vaccination, whether supervisors approach individual workers about vaccine acceptance, and the vaccination status of specific clinical leaders. Other facility-level organizational and management factor items obtained in the survey included workforce data for different provider groups, and facility and community characteristics.

OSHA Bloodborne Pathogens Compliance Questionnaire:

An OSHA Bloodborne Pathogens Compliance Questionnaire was developed for the purposes of this study, based upon key components (see Table 2) identified by the American Hospital Association (AHA) from the OSHA's Final Bloodborne Pathogens Standard. Selected components of the BPR Standard were abstracted from the AHA Compliance Guide and developed into a 88-item questionnaire. Each item involved Likert-type responses regarding the respondent's confidence whether a particular component has been implemented at their

facility or not, on a scale from 0 = "not at all confident" to 3 = "very confident". These data were obtained from Iowa facilities at the baseline assessment.

American Hospital Association Data:

Data from the AHA Guide were obtained for the purposes of further describing the organizational characteristics of hospitals in each of the facilities. Data available in the AHA Guide included classification codes, utilization data, expense, personnel, approval and facility codes. Classification codes included control (government, non-federal; non-governmental not for profit; investor-owned [for profit]; government, federal; and osteopathic); type of service (general medical and surgical; psychiatric; children's; etc.); and stay (short-term, long-term). Approval codes included whether the facility had received Joint Commission on Accreditation of Health care Organizations (JCAHO), approval to participate in residency training by the Accreditation Council on Graduate Medical Education (ACGME), and medical school affiliation reported to the American Medical Association (AMA). Data on the health care system included whether the institution belonged to a specific health care system. Beginning with the 1995-96 AHA Guide, data on physician practice organization codes were available, including: Closed Physician Hospital Organization, Open Physician Hospital Organization Equity Model, Foundation, Group Practice without walls, Independent Practice Organization (IPA), and Multispecialty Organization (MSO).

Facility codes regarding services available within the facilities as reported by the institutions were reviewed by the investigators and considered if they represented characteristics of facilities likely either related to the occupational health program or likelihood of workers' exposure to blood or body fluids. The most common physician practice types in Iowa included: an integrated salary model, foundation, Open PHO, and IPA. Data from the respective AHA Guides corresponding to the time periods of each of the surveys were entered into databases for further analyses.

Health Care Worker Questionnaire:

A mail-out questionnaire was developed to assess occupational exposures, epidemiologic risk factors, selected preventive health measures, and reasons for vaccination based upon risk factors identified or suggested in the literature. Prior to data collection, the study design, cover letter and questionnaire were reviewed and approved by the Institutional Review Board. The questionnaire was pilot tested on a sample of health care worker volunteers, reviewed for clarity, revised and tested again.

A random sample of health care workers stratified by occupation was selected from employment rolls, with the sample drawn in proportion to the occupational distribution at the facility. The occupational strata were: resident physicians, staff physicians, nurses, laboratory workers, housekeepers, and other workers. The sample comprised approximately 17% of the workers considered at risk for exposure to blood and body fluids according to OSHA guidelines prior to initiation of OSHA's mandated bloodborne pathogens training.(1) A cover letter explaining the project and measures taken to protect confidentiality was mailed with the questionnaire. The survey was completed anonymously with individual questionnaires identified only by a code number. Two repeat mailings were performed at three week intervals to improve the response rate.

Demographic data were collected regarding occupation, age, sex, and primary work site. Workers were asked to estimate the number of separate needle or sharps (percutaneous) injuries, and the number of times blood contacted their skin or mucous membranes

(mucocutaneous) in the prior year. The number of influenza vaccine doses received in the prior three years was queried, as an indicator of voluntary vaccine acceptance. Subjects were also asked to indicate their frequency of seatbelt use when driving or riding in a car. Since seatbelt use is legally required in Iowa, this item reflected acceptance of a legally mandated preventive health measure. Health care workers were asked whether they had a prior history of HBV infection and were already immune, as well as the number of doses of HBV vaccine received. Serologic testing was not performed routinely prior to this study unless the worker reported a history of clinical hepatitis or testing was otherwise clinically indicated.

Medical and other health sciences students were not included in the sample, unless they were paid employees of the hospital at the time of the survey. Motivation for HBV vaccine acceptance by medical and physician assistant students was examined in a separate study.(39) Preventive health measures use and motivation for vaccine acceptance among these students has been contrasted with resident and staff physician data from the current survey and reported elsewhere.(39)

A 13-item HBV vaccine acceptance scale and a 15-item vaccine refusal scale were developed, based upon the medical literature, a focus group of health care workers and from pilot testing of the study questionnaire. Workers were asked to rate the relative importance of each item on a 7-point Likert scale, with response options ranging from "Not Important" (1) to "Very Important" (7). Subjects were instructed to complete all items that they felt explained their current hepatitis B vaccination status and intent to be vaccinated (either unvaccinated (i.e. "have not been or do not plan to get vaccinated"), or vaccinated ("have received or are in the process of receiving the vaccine")).

Statistical Analysis:

Institutional Data

Institutional hepatitis B vaccine delivery program effectiveness was modeled based upon institutional hepatitis B vaccine acceptance rates at baseline and at follow-up. Additional multivariate models were developed to identify factors associated with significant changes in the institutional vaccination rate (IVR) over time, among those institutions participating in the baseline and follow-up surveys. Finally, a multiple logistic regression model was developed to identify factors associated with achieving an overall HBV IVR of 90% or greater, the level identified as a target for health care facilities in Healthy People 2000.(2)

Descriptive Analysis of Facility Characteristics

Descriptive information was generated in order to determine whether the characteristics of participating hospitals differed significantly from all Iowa and Virginia hospitals represented in the AHA surveys. The distributions of continuous variables were assessed for normality. The Wilcoxon rank sum test was used to compare the means of continuous variables in the two populations. For binary variables, differences in group proportions were evaluated using Fisher's exact test. All data management and statistical analyses were performed in SAS (SAS Institute, Cary, NC). Alpha was set at 0.05 and all p-values were two-tailed.

Analysis of Overall Institutional Vaccination Rates

The primary outcome variables were the overall institutional hepatitis B vaccination rate (IVR) among employees in each survey. This overall IVR was constructed as a weighted

average of rates among nursing staff, housekeepers, and lab workers, which was considered as a continuous response variable.

Categorical variables were recoded into sets of binary indicator variables. The appropriate scaling of continuous variables was performed by recoding into risk quartiles to assess the relationship with the outcome variable. Continuous variables were assessed for linear and quadratic relationships with the outcome variable, and transformed as necessary. The effect of extreme values and outliers was assessed as described elsewhere.

Univariate descriptive statistics and assessment of simple relationships among the model components were performed. Correlations between the IVR and facility organizational and program characteristics were evaluated with Pearson or Spearman rank correlation coefficients as appropriate.

Multivariate linear regression models were developed to identify important institutional determinants of the IVR at baseline and at follow-up. All variables associated with the IVR ($p<0.25$) were considered as candidate variables for the initial model. Model building was performed, based upon theoretical relationships between the components and the outcome variables. Assessment for collinearity was performed and highly collinear variables eliminated. All multivariate models developed for this project were examined for goodness of fit, assessed for the influence of outliers and theoretically important interactions were considered. Alpha was set routinely at 0.05 and all p-values were two-tailed, unless otherwise noted.

Baseline Overall Institutional Vaccination Rates

Univariate analyses of the 1992 data utilized simple linear regression, with an alpha level ($p<0.01$) chosen to adjust for multiple comparisons. Multivariable analyses involved multiple linear regression, with the dependent variable the overall HBV IVR. Only variables associated with the IVR at univariate p-values <0.25 were considered in constructing the model. The final model was selected using forward and backward stepwise procedures. The importance of each variable in the model was verified by evaluation of the Wald statistic for the variable and the global F statistic, assessment of the effect on the model coefficient of variation, and comparison of each estimated coefficient with the coefficient from the previous model in the stepwise analysis.

For backward stepwise variable selection, variables that did not significantly improve the fit of the model using the likelihood ratio test at $p<0.10$ were removed and the models reestimated. Inclusion of previously removed variables was considered at each step. If the variable did not significantly improve the fit of the model using the likelihood ratio test at $p<0.10$, the variable remained excluded.

For the forward stepwise variable selection procedure, variables that did not significantly improve the fit of the model using the likelihood ratio test at $p<0.10$ were not added to the model. Exclusion of previously included variables was considered at each step. Variables that based on the likelihood ratio test at $p<0.10$ did not significantly improve the fit of the model were removed, and the models reestimated until a final parsimonious model was obtained.

Change in Overall Institutional Vaccination Rates

A multivariable model was developed among those Iowa facilities providing data at the baseline and follow-up surveys to assess changes in the overall IVR at those facilities. Both

baseline (1992-based) variables and those variables demonstrating changes in program or institutional factors over the 2.5 year follow-up period were considered in analyses of the change in vaccination rates over time. After careful consideration of a variety of measures, one observation in the follow-up data was a misreported value and was discarded. The analyses of these data were conducted similarly to those of the baseline data. However, residual normality was unsatisfactory for certain variables in these analyses, so the models were retested using robust regression procedures (Stata Inc.). Appropriate first-order interaction terms were considered for inclusion in the models. All p-values reported were two-tailed.

Overall Institutional Vaccination Rates

Data from the follow-up survey were analyzed by developing a logistic regression model to identify factors associated with whether an institution achieved an overall HBV IVR of 90% or greater among workers at risk. Utilizing the methods of Hosmer and Lemeshow, model building was performed using a forward step-wise procedure with inclusion and exclusion p-values of 0.15.(40) All clinically relevant one-way interactions were considered for evidence of important effect modifiers. Only terms with p-values < 0.05 were included in the final models. The magnitudes of the effects were expressed as odds ratios in the final logistic models. The performance of each of the logistic models was evaluated using the Hosmer Lemeshow goodness of fit statistic (as a measure of model calibration) (41; 42) and the c-statistic (as a measure of model discrimination).(43)

Analysis of Program Effectiveness Factors

Multiple logistic regression models were developed to identify characteristics associated with achieving HBV institutional vaccination rates (IVR) of 90% or greater. Models were constructed separately for RNs, LPNs/NAs, and laboratory workers. Data collected from 190 health care facilities in Iowa and Virginia were used in the analyses (N_{IA}=120, N_{VA}=70).

Univariate logistic regression analyses were completed for each occupational group using both institutional survey and AHA data. The dependent variable was dichotomized to reflect the binary outcome of interest. Categorical variables were coded using the appropriate number of design variables. The relationship between each of the continuous covariates and the logit was evaluated for linearity. Quadratic terms were created when necessary.

Characteristics at least moderately associated with HBV IVRs of 90% or greater ($p< 0.25$) were grouped according to theoretical relationships among the institutional factors of interest. Multiple logistic regression models were then individually constructed for each of the factors: program characteristics, clinical leader involvement, educational program, vaccination access, and occupational health program. This method of subsetting variables into commonalities was similar to the approach used by Harrell et. al. in which variables were clustered to reflect intercorrelations among related measures.(43) They found when dealing with a large number of variables, the technique provided a more interpretable model with a higher c statistic than standard variable selection.

Backward variable selection was utilized with appropriate methods for assessing the model's fit. The importance of each of the variables in the model was verified by evaluating the Wald statistic and the G likelihood ratio test statistic. Variables comprising each of the factors, which demonstrated a significant association with the outcome variable ($p <0.1$), were used in the final model. The model was then examined in the same manner discussed previously. The

estimated coefficient was compared to the coefficient from the full model to assess potential confounding. Clinically relevant interaction terms were created in order to evaluate possible effect modification. The c statistic and Hosmer-Lemeshow goodness of fit statistic were used to the assess adequacy of the models. (41-43)

Health Care Worker Data:

Factor analysis was performed as a data reduction technique to determine which reasons for accepting (or intending to accept) the series or not accepting (or not intending to receive) the vaccine appeared to be linked. All items that loaded on a single factor were combined into single scales for vaccine acceptance or refusal.

These factors corresponded to a subset of the domains identified by Cummings et. al.(44) that explained health actions. These domains were used to label the factors. Labels assigned to the factors associated with vaccine refusal (Appendix 1) included: *Threat of disease* (e.g., concern about side effects of the vaccine); *Knowledge of disease* (e.g., insufficient information about the disease); *Access to care* (e.g., too busy/never enough time); *Risk denial* [e.g., not necessary (not at increased risk for hepatitis B)]; and *Social influence* (e.g., behavior of someone I respect). Labels assigned to the factors associated with vaccine acceptance (Appendix 2) included: *Social influence* [e.g., recommendation of spouse/significant other; behavior of someone I respect (role model)]; *Threat of disease* (e.g., possible restriction from patient care if infected; previous needlestick/sharps injury); and *Knowledge of disease* (e.g., information obtained from professional sources; information letter from employer).

The reliability of the acceptance and refusal scales, as estimated by Cronbach's alpha statistic, were 0.82 and 0.72, respectively. The demographic characteristics of study participants were compared to those of the overall population from which the sample was drawn in order to evaluate for evidence of response bias. Health care workers with a prior history of hepatitis B or natural immunity were excluded from all subsequent analyses. Stratified analyses were performed by occupation to examine the reasons for vaccine acceptance and refusal. Differences in the reasons for vaccine acceptance among persons in each occupational group were evaluated with independent samples t-tests to compare mean Likert scores, using tests for equal or unequal variances as appropriate. The results of the stratified analyses of the reasons for vaccine acceptance were used to combine occupational groups for further analyses.

A random sample was selected, stratified by occupational category, which represented two-thirds (N=599) of the study participants, to derive or develop the logistic regression models to identify determinants of vaccine acceptance. This initial sample was referred to as the "calibration sample." The logistic regression models were then validated on the remaining one-third of the sample (N=299), the "validation sample." If the logistic regression models from the calibration sample adequately predicted the results in the validation sample, the entire sample was combined and the models reestimated.(41)

Contingency table analyses of the association between demographic, occupational and preventive health variables and the outcome of vaccination were assessed with a likelihood ratio chi square test for nominal and ordinal variables.(40) Continuous variables were examined individually in univariate logistic models. Ninety-five percent confidence intervals (CI_{95}) were calculated for the odds ratios. Alpha was set at 0.05 and all p-values were two-sided. All statistical procedures were performed using SPSS (Statistical Package for the Social Sciences, Chicago, IL).

Multivariable logistic regression models were developed to predict initiation (e.g., one or more doses), and completion (e.g., three or more doses) of the HBV vaccine series considering all variables associated with vaccine acceptance from the univariate analysis ($p<0.25$).(40; 45) The importance of each variable in the models was verified by evaluation of the Wald statistic and comparison of each estimated coefficient with the coefficient from the univariate model. The fit of each model was evaluated using the likelihood ratio test. Variables that did not significantly improve the fit were removed and the models reestimated. Appropriate first-order interaction terms were considered for inclusion in the models. The final logistic models were also evaluated for the adequacy of fit using the Hosmer-Lemeshow goodness-of-fit statistic which compares expected and observed values in a dataset across deciles of risk.(40; 41)

Results

A total of 133 of 141 (94%) ISSS facilities participated in the baseline survey in 1992 prior to the enforcement of OSHA's Bloodborne Pathogens Rule (BPR). A total of 116 of 138 facilities participated in the follow-up survey (84% response rate). Comparison of data from the 1992 and 1994 AHA Guides demonstrated that the organizational characteristics of the hospitals participating in either survey were similar to those of all the facilities in the state (Table 3). It is important to note that these data were available only for hospitals. These data were available from 122 Iowa hospitals in the baseline survey and 107 Iowa hospitals at follow-up.

Vaccine implementation programs differed, in terms of measured program characteristics, by size of the institution and location of the county (urban versus rural). For example, vaccine provision at a health fair ($p=0.006$) and provision to physicians at the worksite ($p=0.007$) were significantly different in rural versus urban hospitals. Differences in programs by hospital size included: vaccination records availability in a computerized database ($p=0.035$), and provision to nurses at the worksite ($p<0.0001$).

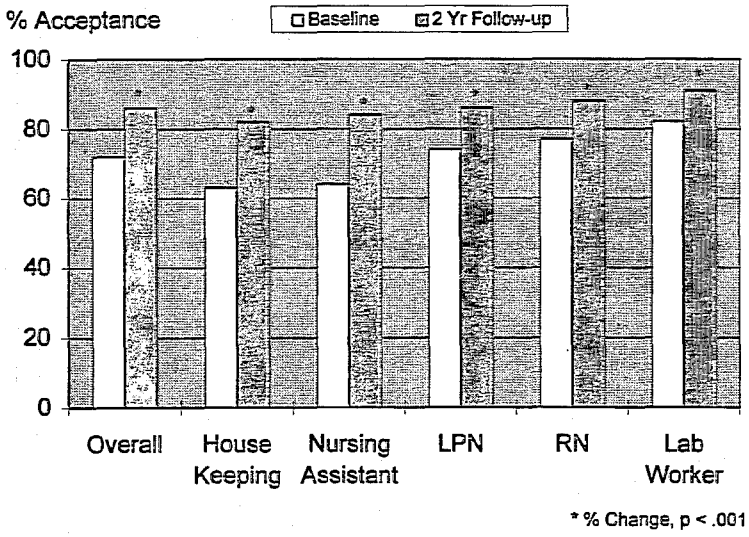
A wide range of program and organizational factors were significantly associated with the overall HBV IVR at baseline (Table 4). Workforce variables such as the proportion of registered nurses (RNs) and laboratory workers (LWs) among the workforce were positively associated, and the proportion of nursing assistants (NAs) negatively associated with the IVR. Management issues, such as a policy requiring the HBV vaccine for employment of certain occupational groups within a facility, was strongly associated with the IVR. Occupational health program aspects, such as whether serologic response was routinely checked after receipt of the initial series, and whether the institution had a policy that covered occupational hepatitis B, were of borderline importance. Importantly, management commitment to the vaccine delivery program, as measured by the assessment of the number of specific clinical leaders that had actively encouraged the HBV vaccination of workers or received the vaccine themselves in the past, was strongly related to the summary IVR.

A number of other variables that had been considered potentially important program characteristics were not significantly associated with the HBV IVR. Factors such as the availability of occupational vaccination records in a computerized database, and sending reminder letters to return for follow-up doses of vaccine were unrelated to the summary IVR at baseline. Similarly, offering the vaccine at meetings or at the worksite for registered nurses or other occupational groups were both unrelated to the overall rate.

The overall mean IVR (three or more doses) at the baseline assessment in Iowa health care facilities was 72%, excluding physicians (Table 5). The summary HBV IVR in Iowa

facilities was 63% among housekeepers, 64% among nursing assistants, 74% among licensed practical nurses, 77% among registered nurses, and 82% among laboratory workers. At the time of follow-up, the IVR had significantly increased in all occupational groups for which data was available (Figure 1). The percent increases were 14% overall, and ranged from 9% to 20% in different occupations. Housekeepers remained the least protected group with a mean immunization rate of 82%, and lab workers had the highest rate at 91%. Unfortunately, most institutions do not keep records on physicians, since they are not typically considered employees of the health care facility. Where available, data suggested that rates of HBV acceptance among physicians remained unacceptably low.

Changes in Hepatitis B Vaccine Acceptance



Multivariate linear regression analysis to predict the facility IVR at baseline identified a four variable model with an adjusted R square of 0.45 (Table 6). The baseline regression model to predict the IVR identified the importance of active encouragement of and participation in vaccination by leaders, the proportion of registered nurses in the workforce, and a requirement of vaccination for registered nurses. The number of clinical leaders (out of five) vaccinated against hepatitis B was strongly and positively related to the IVR. Similarly, the level of management commitment by the Chief of Staff to the institutional HBV vaccination program was also independently and positively associated with the IVR.

The multivariate linear regression model of factors associated with change in the HBV IVR at follow-up identified a five factor model with an adjusted R-squared of 0.599. Workforce factors that were important included the number of registered nurses at a facility and the change in the proportion of lab workers over time. Program factors included whether the vaccine was provided at the worksite and at meetings for housekeepers (Table 7). Repeating these analyses with robust regression techniques identified the same factors except for provision at meetings for housekeepers which was no longer significant, but necessary in the model for stabilization of the results.

Logistic regression identified three factors associated with achievement of an overall 90% rate of HBV vaccination in the health care facilities surveyed (Table 8). These variables included the transformed baseline vaccination rate, active encouragement of the nursing director, and location in a non-Standard Metropolitan Statistical Area (SMSA).

The results of modeling of the combined Iowa and Virginia data to identify factors associated with achievement of a 90% level of worker HBV immunization in specific occupational groups were particularly enlightening. Although the final models varied somewhat

from one occupation to the next, as expected based on our health care worker level data, remarkable consistency between groups was evident. The model for achievement of this target rate of immunization included the following factors (Table 9): fewer outpatient visits, vaccination of leaders (OR = 7.2), use of an invitation letter to receive the vaccine (OR=2.0), and use of a reminder to complete the series (OR=15.0). The model for achievement of this target among other nursing personnel (LPNs and NAs) included (Table 10): vaccination of leaders (OR=2.6), encouragement by leaders (OR=3.9), delivery at the worksite (OR=3.2), and monitoring of universal precautions compliance by coworkers and others (OR=3.8). Finally, the model for achieving this target among laboratory workers included (Table 11): lower facility complexity, vaccine delivery at the worksite (OR=2.6), and monitoring of universal precautions compliance by coworkers and others (OR=4.4).

Health Care Worker Study:

A total of 1018 questionnaires were mailed and 919 were returned, for an overall response rate of 90.3%. Study participants were not significantly different from the overall population in terms of occupation, age, or gender. Twenty-one workers reported a history of hepatitis B or prior natural immunity and thus were excluded from all subsequent analyses.

Among workers without a history of hepatitis B or prior natural immunity (N=898), 54% (N=482) had completed the three dose series, while 70% (N=626) had received one or more doses (Table 12). Workers having either initiated or completed the vaccine were significantly younger (mean 37 years) than those remaining unvaccinated (mean 40 years, CI_{95} for the difference = 1.7, 4.8, and CI_{95} = 1.8, 5.0, respectively). A slightly greater proportion of women than men had initiated the series (72% vs. 66%, OR=1.2, CI_{95} = 1.0, 1.5, p=0.056) and had completed it (55% vs. 51%, OR=1.2, CI_{95} = 1.0, 1.4, p=0.096). Vaccination varied significantly by occupation: 80% of house officers had completed the series, versus 70% of registered nurses, 60% of licensed practical nurses, 61% of laboratory workers, 51% of nursing assistants, 42% of staff physicians, and 23% of housekeepers. Vaccination rates were also significantly higher in certain clinical settings (Table 13, $p<0.001$): workers located on specialty wards, intensive care units, and in operating rooms had significantly higher rates of vaccine series completion than workers in other areas.

Overall, 23% of workers reported a sharps injury and 57% noted sustaining a mucocutaneous blood exposure in the prior year. Workers who reported any mucocutaneous blood exposures in the prior year had a mean of 22.5 exposures. Additionally, there was a mean of 2.7 injuries among those with at least one percutaneous injury in the prior year. Physicians had the highest rate of multiple injuries (≥ 2) in the prior year: houseofficers (25%), staff physicians (16%), registered nurses (11%), laboratory workers (5%), housekeepers (4%) and others (11%).

Sixty-nine percent (N=189) of workers declining the HBV vaccine had not been vaccinated for influenza in the prior three years, compared with 49% (N=308) of those that had received at least one dose of HBV vaccine and 47% (N=226) of those completing the series. Eight percent (N=22) of workers declining the HBV vaccine reported using seatbelts less than half the time they rode in a car, compared to fewer than 5% of those initiating or completing the vaccine.

The highest-ranked reasons for refusal (Appendix 1) included: "not at increased risk" (mean=3.0); "concern about vaccine side effects" (mean=2.8); "insufficient information about

the vaccine" (mean=2.6); "have not received a letter of invitation" (mean=2.2); "too busy/never enough time" (mean=2.2), and "concern about possible jaundice due to vaccination" (mean=2.2). The highest-ranked reasons given for vaccine acceptance (Appendix 2) included: "information obtained from professional sources (mean=5.1); "providing care for hepatitis patients" (mean=4.0); "recommendation of a supervisor" (mean=3.3); and "recommendation of a physician" (mean=3.1).

Factor analysis of the reasons for vaccine refusal resulted in five factors that explained 66% of the variance (Table 14A). Similarly, the factor analysis yielded three factors that explained 55% of the variance among those accepting the vaccine (Table 14B). Items related to "threat of disease" explained the greatest proportion of the variance among those declining and the second largest proportion among those accepting the vaccine. In contrast, questionnaire items related to "social influence" explained the largest proportion of the variance among those accepting the vaccine. "Social influence" was also important in vaccine refusal, with items related to role model behavior and physician recommendations loading on the 1st and 5th factors, respectively. Items related to "knowledge of disease" were responsible for the second and third largest proportions of the variance in the two groups, respectively. "Access to care" items were the third most important factor among those declining the vaccine (Table 14A). Denial of risk was important among those declining the vaccine.

None of the reasons for HBV vaccination among registered nurses and licensed practical nurses were significantly different, thus the two groups of professional nurses were considered together for subsequent analyses. Additionally, laboratory technicians, other workers, and students also had similar reasons (1 or fewer significant differences) for vaccine acceptance and were combined. The other occupational groups differed considerably (three or more significant differences) in their reasons for vaccine acceptance and were thus considered separately in the logistic regression analyses.

Significant univariate predictors of initiating the vaccine (one or more doses) in the calibration sample (Table 13) included: age, occupation, work site, frequency of blood exposures in the prior year, frequency of sharps injuries in the prior year, and frequency of previous influenza vaccination. Frequency of seatbelt use approached significance (p=0.082), although gender was not related to series initiation. The same variables were also associated with vaccine series completion, although age (p=0.117) and seatbelt use frequency (p=0.165) were not significant.

The logistic model for vaccine series initiation in the calibration set included: age, occupation, frequency of blood exposure, and prior influenza vaccine acceptance. Using a cutoff probability of 0.50, the sensitivity of the calibration model was 89%, specificity 34% and accuracy 74%. The same logistic model in the validation sample had sensitivity of 89%, specificity 47%, and 75% overall accuracy. In the calibration sample, the Hosmer-Lemeshow (HL) goodness of fit test yielded a Chi-square statistic of 6.85 (8 d.f.) (p=0.55).(41) In the validation sample, the HL goodness of fit test Chi-square statistic was 9.26 (8 d.f.) (p=0.32).

In the calibration sample, the logistic model for vaccine series completion included: occupation, frequency of blood exposure, prior influenza vaccine acceptance, and frequency of seatbelt use. The sensitivity of this model in the calibration sample was 71%, specificity 67% and overall accuracy was 69%. Similar results were obtained in the validation sample: sensitivity was 65%, specificity 72% and overall accuracy 68%. The HL goodness of fit test demonstrated that the fit of the model in both the calibration (Chi-square=5.03, 8 d.f., p=0.75) and validation samples (Chi-square=10.80, 8 d.f., p=0.21) was adequate.(41)

Age was inversely associated with HBV vaccine series initiation in a linear relationship. An increased frequency of mucocutaneous exposure to blood was also independently related to initiating and completing the vaccine series. However, although an increased frequency of percutaneous injury was a predictor of hepatitis B vaccination, the relationship was not independent. Prior influenza vaccination was related to both HBV series initiation and completion in the calibration logistic regression models. Workers reporting influenza vaccinations in the prior three years were more likely to also have received the HBV vaccine. Reported frequency of seatbelt use was also related to vaccine series completion in the calibration sample, although the association was of borderline significance (p=0.069).

Following the fit and validation of both logistic models, the entire sample was combined and the parameters reestimated using the variables derived from the calibration sample. Each of the previous variables remained significant, with the exception of seatbelt use frequency in the model for vaccine series completion (p=0.28). Since this variable was of borderline significance in the calibration set and was of marginal clinical relevance, the variable was removed and the model reestimated (Table 15). The final model for vaccine initiation had a sensitivity of 88%, a specificity of 42%, an overall accuracy of 74% and HL goodness of fit Chi-square statistic of 8.55 (8 d.f., p = 0.38). Similarly, the revised model for vaccine series completion had a sensitivity of 71%, a specificity of 68%, an overall accuracy of 69%, and a HL goodness of fit Chi-square statistic of 3.08 (8 d.f., p = 0.93).

Discussion

Despite the availability of a safe, effective vaccine provided at no cost to the employee, an important proportion of occupationally-exposed workers in community facilities had not completed the vaccine series and many remained completely unvaccinated. These data confirm the need for additional efforts to improve vaccine delivery to health care workers.

OSHA issued a federal standard in December 1991 to attempt to reduce occupational exposure to bloodborne pathogens.(1) The major components include: 1) the availability and offering of hepatitis B vaccine to all workers occupationally exposed to blood, and 2) institutional provision of the vaccine free of charge to all exposed employees. Data from this study indicate that components of the guideline have been effective in reaching previously unvaccinated workers.(46) These studies demonstrate that the institutional levels of HBV vaccine acceptance among all occupational groups at risk in hospitals have significantly increased since the publication of OSHA's Bloodborne Pathogens Rule (BPR).

The most important independent predictors of vaccination at the worker level included occupation, frequency of mucocutaneous blood exposure, prior influenza vaccination, and age. Among those workers remaining unvaccinated, concern about side effects of the vaccine, knowledge of the disease and their risk, and access to the vaccine were the major factors identified. Social influence was clearly the major factor related to vaccine acceptance, although perceived risks and knowledge of the disease were also important. These factors may be useful for identifying health care worker groups that should be specifically targeted to increase effective delivery of the vaccine. Further studies in additional populations should be performed to replicate these findings and to confirm their importance.

In developed countries, two strategies have been used for the control of HBV infection in health care settings. Both the use of HBV vaccine for workers at risk and the consistent use of isolation materials have contributed to a decrease in occupational HBV infections.(47; 48)

Convincing demonstration of the role of isolation in preventing HBV infection was observed in hemodialysis units prior to availability of the vaccine.(49) Importantly, recent data demonstrates that health care providers' knowledge of the epidemiology of the disease is inadequate.(24; 27) Our results suggest that education targeted at increasing health care workers' knowledge of the disease, the risks of occupational exposure to blood and the safety of the vaccine are likely to be important components of training. Additionally, emphasis of the need for routine use of barrier isolation materials in appropriate settings may also be critical.

It has been suggested that repeated educational programs may be effective in increasing vaccine acceptance.(24; 35; 36) In one series, various types of fear and lack of knowledge were cited as reasons for refusal by 73%; the most common reason for acceptance (36%) was information from professional sources.(35) The most frequent reasons given for noncompliance with HBV prescreening and immunization during a period when only the plasma-derived vaccine was available included a concern about the safety of the vaccine (33%), and forgetting or being "too busy" (16%).(50) In a recent study that offered the plasma-derived vaccine free of charge to hospital personnel in Bangkok, lack of knowledge and fear of side effects were the reasons given in 46% of refusals.(24) Although vaccine acceptance has been less than optimal, the actual impact of how concern about the vaccine's safety affects compliance has not been adequately documented.(51) Much of the potential concern about safety should have been relieved with the development of a recombinant hepatitis B vaccine. However, our results demonstrate that the perceived threat or risk of disease (e.g. concern about side effects) and disease knowledge were the most important factors in vaccine refusal. In addition to evidence for a significant effect at the institutional level, these results suggest an important potential role for educational interventions for the individual worker.

Access to care is an important theoretic concern in the appropriate delivery of medical services.(52) Several studies have suggested that institutional vaccine delivery factors such as access to the vaccine and vaccine provision approach may be important in determining the vaccine acceptance of health care providers. (18; 19; 23; 50) Access to care was an important factor in vaccine refusal in our health care worker study, indicating a potential role for delivery of the vaccine at the worksite, at departmental meetings, or during extended clinic hours. Access to the vaccine was also of importance in our institutional models for achieving recommended levels of immunization among certain occupational groups. Access to the vaccine was generally good overall, thus this group of factors did not appear to be important in the summary rates. However, within specific institutions where access to the vaccine is more variable, and for certain occupational groups, it may be particularly important to improve availability of the vaccine. Effective approaches would seem to include delivery of the vaccine at the worksite, as well as approaches to actively invite workers to initiate and return for subsequent doses of the vaccine.

Using logistic regression analysis, Thomas and colleagues found that only race and the nursing occupation were independently associated with lack of vaccination.(23) Israsena et al. reported that age, nature of work, time in the profession, knowledge of hepatitis B, confidence in the efficacy and safety of the vaccine, and contact with blood products were strongly associated with vaccine acceptance.(24) In our study, occupation was an independent predictor of both vaccine series initiation and completion. However, although age was associated with vaccine acceptance, controlling for other variables, the association was observed only for series initiation. Data on duration of employment was not collected, which could potentially confound the relationship between vaccine acceptance and age and occupation. Additionally, the racial and ethnic distribution of the population in the surrounding

State is approximately 94% White, non-Hispanic; thus, data were not collected to examine this variable. Other factors including preventive health behaviors (e.g., prior influenza vaccination), and the frequency of mucocutaneous occupational blood exposures were independently related to acceptance. These results are consistent with those of Murata and colleagues who reported that vaccine acceptance among physicians varied by physician gender, years since graduation, level of training and specialty.(21) Taken together, these results suggest that tailoring the vaccine delivery approach to specific occupational groups at risk and targeting employees with frequent blood exposure may be particularly effective.

There are several methodological differences in the current study of health care workers compared to previous work on HBV vaccination in health care workers. First, data were collected on a stratified random sample of all health care workers determined to be at occupational risk for exposure to blood and body fluids. Most prior studies have either utilized a convenience sample or studied a single group of workers.

Second, multivariate statistical techniques have been used infrequently in prior studies of vaccine acceptance.(23) In the current study, factors potentially associated with vaccine acceptance were examined using multiple logistic regression to identify independent predictors of initiating and completing the vaccine series. The results were subsequently validated in an unstudied subsample of subjects. Although uncertainty exists regarding the determinants of vaccine acceptance, this approach would seem the most appropriate to consider the variety of different factors that are potentially related.

Third, most previous studies have reported simple proportions of workers responding to possible reasons to accept or refuse the vaccine. In the current study, factor analysis was used to examine concurrently suggested reasons for accepting or declining the vaccine.

Fourth, most published studies have either been relatively small or had relatively low response rates. The sample size and response rate in the current study allows reasonably precise estimates of the rates of vaccine acceptance and examination of their determinants.

Finally, in most early studies of vaccine acceptance, many workers were very concerned about the safety of the vaccine. Our study was performed at a time when considerable evidence has accumulated concerning the safety and efficacy of the recombinant vaccines; thus, these data may be more representative of current determinants of vaccine acceptance. Yet, our data suggests that concern about potential side effects is still an important deterrent to vaccination.

Several important limitations should also be noted. This worker-level study was performed at a single teaching hospital; thus, the results may not be generalizeable to workers at other types of facilities. The study also relies on self-reported data for frequency of occupational exposure, which had not been independently validated. However, a variety of investigators have shown that occupational exposure to blood is greatly underreported and that self-reports appear to be the most sensitive measure.(53)

At baseline, prior to the time when OSHA's BPR became enforceable in July 1992, institutional levels of vaccine acceptance were related primarily to three factors: workforce composition (proportion of registered nurses in the workforce), requirement of the vaccine for employment of registered nurses, and management support. Management support was demonstrated to be important, both in terms of the active encouragement of vaccination by clinical leaders, and the acceptance of HBV vaccination by leaders themselves.

A number of health care facilities have achieved the Healthy People 2000 goal of 90% HBV vaccination levels among their health care workers at risk, although many facilities have not. Levels of vaccine acceptance are highest among laboratory workers and lowest among physicians and housekeepers. However, data on physicians is limited since many facilities do not consider them employees and do not have data available. The most important factors associated with achievement of this target rate of vaccine acceptance within institutions included: location in a rural area, active encouragement of vaccination by the nursing director, and the baseline vaccination rate within the institution.

Our findings of the importance of using letters to formally invite workers to receive the vaccine and to return for subsequent doses in achieving high rates of immunization within health care facilities is particularly exciting. These findings are consistent with the results of Sellors and colleagues studying adults attending a community-based sexually transmitted diseases clinic that certain groups are at increased risk of noncompliance with the second dose of vaccine, but are highly responsive to telephone reminders.(54)

There are a number of important limitations in the ability of many community-based health care facilities to monitor and protect the health of their employees. The availability of an electronic database containing levels of vaccination and exposures within the health care workforce is an important limitation in many facilities. Additionally, data on physicians are limited since many facilities do not consider them employees and have data available. A number of studies have found that physicians are a particularly difficult group to reach and may require special efforts.(21; 22; 25; 55)

The finding of measures of institutional complexity being inversely related to the vaccination rate may be reflective of the relatively greater social influence of administrative and clinical leaders in smaller health care facilities where they have greater contact with front-line workers. Further, rural hospitals, in general, have higher levels of worker vaccination than urban health care facilities. Based on our studies of health care workers and facilities, we hypothesize that these differences are due to the greater recognition of and social influence of clinical leaders, such as the infection control practitioner, in a smaller facility.

Further study is needed using appropriate intervention research methods to determine optimal, effective approaches to increase levels of vaccine acceptance in health care settings.(56; 57)

CONCLUSIONS

The studies supported by this grant have significantly advanced our understanding of occupational health programs in community health care facilities to provide the hepatitis B vaccine (HBV) to health care workers. Most importantly, these studies demonstrate that both organizational and program factors, as well as worker-level factors, are important in the acceptance or delivery of the HBV vaccine to health care workers.

Taken together, these results demonstrate the importance of management commitment and support to the program, as well as specific modifiable program factors that improve access to the vaccine, and eliminate barriers to delivery. Program components such as actively reminding or inviting workers to initiate and return for vaccine doses, and an active occupational health program with monitoring of compliance with universal or standard precautions are each

independently related to achieving recommended levels of HBV vaccination within health care facilities.

Finally, the current study was not designed to be an exhaustive analysis of all possible determinants of vaccine acceptance or delivery. Further studies investigating the role of other epidemiological, behavioral and health care delivery factors are likely to further elucidate this difficult public health problem. The most convincing evidence of the importance of these factors in influencing institutional vaccination rates would come from a well-designed, prospective clinical trial in multiple institutions. However, this work has identified a number of important, modifiable institutional and program factors, which appear to be related to achieving high levels of HBV vaccination within health care facilities. These results suggest that there is no time like the present to begin to introduce and evaluate these approaches to better protect workers and their patients from occupational and iatrogenic hepatitis B infection.

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TABLES

Table 1 Schematic of Study Plan

	Methods	Target Group Variable(s)	Outcome Measures	Predictors	Analysis
Study I	Longitudinal surveys (questionnaire)	Health care institutions (infection control practitioners in Iowa)	Vaccine compliance rates	Educational program, access, role model behavior, promotion level; OSHA compliance	Multiple regression model Transformation of data
Study II	Institutional validation study (same questionnaire as Stage I)	Health care institutions (infection control practitioners in Virginia)	Vaccine compliance rates	Educational program, access, role model behavior, promotion level; OSHA compliance	Multiple regression model Compare validation model to original model
Study III	Worker study	Health care workers Stratified Sample	Vaccine acceptance A) Series initiation B) Series completion	Beliefs, attitudes Occupation, work-related factors, preventive service use, demographics	Factor analysis Multiple logistic regression models Derivation and validation models

Table 2. Factors of Interest in the Institutional Survey.

Factor	Items	Measure	Type Variable
Community Characteristics	Community Size	Population	Continuous
	Urban/Rural	SMSA county	Dichotomous
	Proportion urban	% population in single incorp. place >2500	Continuous
Facility Characteristics	Acute Care Beds	#/Institution	Continuous
	Chronic Care Beds	#/Institution	Continuous
	Acute Admissions	#/Year	Continuous
	Chronic Admissions	#/Year	Continuous
	Proportion Occupation	% Workforce in Occupation	Continuous
Clinical Leader Involvement	Leader Vaccination	# Vaccinated/5	Categorical
	Active Encouragement	# Active/5	Categorical
	Approach Individually	# Approach/5	Categorical
Educational Program	Invitation Letter	Frequency/Year	Categorical
	Format (lecture, etc)	Frequency/Year	Categorical
	Health Fair	Frequency/Year	Categorical
Access	Worksite Provision	# groups/4	Categorical
	Dept. Mtg. Provision	# groups/4	Categorical
	Availability	Hours/week	Categorical
HBV Experience	Occupational HBV	HCWs Developing HBV	Categorical
	Patient HBV	Patients with HBV in past yr.	Categorical
Occupational Health Program	Employment Requirement	# Occup. Groups Req./4	Categorical
	Record Accessibility	Computerized Database	Categorical
	Vaccination Follow-up	Reminder Letter	Categorical
	Serological Response	Checked or Not	Categorical
OSHA Bloodborne Pathogens Compliance Score	Exposure Control Plan	Written Plan (10 components)	Score 0-30
	Engineering Controls: Sharps	Written Plan, Training (12)	Score 0-36
	Safe Work Practices	Training Components (11)	Score 0-33
	Personal Protect. Equipment	Provision, Training, Replace (16)	Score 0-48
	Rubber Gloves	Access, Training, Required (9)	Score 0-27
	Housekeeping	Written Procedures, Training (9)	Score 0-9
	Compliance Monitoring	Written Monitoring Procedures (8)	Score 0-24
	HBV Vaccine	Provision Plan & Program (13)	Score 0-39
Overall Score			Continuous (0-264)

Table 3. Descriptive characteristics of participating hospitals and all hospitals in Iowa and Virginia. [1]

Characteristics	Participating Hospitals	N	All Hospitals	N
Beds (mean)	140	174	162	256
Admissions (mean)	3976	158	4247	222
Census (mean)	85	158	97	222
Outpatient visits (mean)	46408	157	62062	222
Births (mean)	468	158	500	222
Total Cost (mean)	27679	154	31463	210
Personnel (mean)	467	157	532	221
JCAHO Accreditation	120 (70.6%)	170	185 (73.1%)	253
Medical School Affiliation	32 (18.8%)	170	54 (21.3%)	253
Residency Training Approval	25 (14.7%)	170	41 (16.2%)	253
Cancer Program	32 (18.8%)	170	51 (20.2%)	253
Cardiac Catheterization Lab	41 (24.0%)	171	68 (26.8%)	254
Cardiac Intensive Care Services	37 (21.6%)	171	57 (22.4%)	254
Emergency Department	148 (86.5%)	171	201 (79.1%)	254
HIV-AIDS Services	28 (16.4%)	171	50 (19.7%)	254
Home Health Services	103 (60.2%)	171	140 (55.1%)	254
Long Term Care	70 (40.9%)	171	99 (39.0%)	254
Medical Intensive Care Services	107 (62.6%)	171	149 (58.7%)	254
Neonatal Intensive Care Services	21 (12.3%)	170	36 (14.2%)	254
Obstetrics	125 (73.1%)	171	166 (65.3%)	254
Occupational Health Services	82 (47.9%)	171	121 (47.6%)	254
Oncology Services	90 (52.6%)	171	126 (49.6%)	254
Open Heart Surgery	19 (11.1%)	171	40 (15.7%)	254
Outpatient Surgery [2]	150 (87.7%)	171	201 (79.1%)	254
Trauma Center	16 (9.3%)	171	30 (11.8%)	254

Note: [1] American Hospital Association Data.
[2] Significantly less than all hospitals ($p < .05$).

Table 4. Univariate Factors Associated with the Overall Institutional Hepatitis B Vaccination Rate in Iowa Hospitals at Baseline (N=133 facilities)

Variable	ß	Standard Error	Significance
Workforce Variables			
Proportion RNs	0.481	0.134	<0.001
Proportion NAs	-0.414	0.115	<0.001
Proportion LWs	1.715	0.451	<0.001
Emergency Department	25.612	11.580	0.029
Program Characteristics			
Serologic Response to Vaccine			0.075
Checked only after exposure	9.433	6.069	0.123
Checked after 3 or more doses	11.772	5.141	0.0237
Vaccine Required for Workers			
Nurses	15.926	5.225	0.003
Housekeepers	19.825	5.464	0.004
Lab Workers	19.520	5.189	<0.001
Physicians	24.948	10.008	0.014
Institutional Disability Policy Covers Occupational Hepatitis B	7.486	4.138	0.072
Management Support			
Active Encouragement by Leaders			
Infection Control Chair	17.519	10.323	0.092
Chief of Staff	8.063	4.812	0.097
Vaccination of Leaders			
Infection Control Practitioner	9.052	4.845	0.064
Infection Control Chair	12.117	4.170	0.004
Chief of Staff	6.877	4.142	0.0995
Nursing Director	12.993	4.272	0.003
Lab Director	19.976	5.657	<0.001

Table 5. Changes in Mean Rates of Hepatitis B Vaccine Acceptance Among Workers in Iowa Institutions Post-Implementation of OSHA's Blood borne Pathogens Rule (N=103 institutions).

Worker Group	Baseline Rate	Follow-up Rate	% Change	Significance
Overall	72%	86%	14%	< 0.001
Housekeeping	63%	82%	19%	<0.001
Nursing Assistants	64%	84%	20%	<0.001
Licensed Practical Nurses	74%	86%	12%	<0.001
Registered Nurses	77%	88%	11%	<0.001
Laboratory Workers	82%	91%	9%	0.001

Table 6. Multivariate Linear Regression Model of Institutional and Program Factors associated with the Institutional Hepatitis B Vaccine Rate at Baseline in Iowa Hospitals (N=133).

Variable	ß	Standard Error	Significance
Proportion of Registered Nurses	0.363	0.130	0.006
Vaccination Required for Registered Nurses	10.494	4.080	0.012
Active Encouragement			
Chief of Staff	6.503	3.720	0.084
Number of Leaders Vaccinated			
One	28.821	11.911	0.018
Two	52.000	10.986	0.0001
Three	59.742	10.333	0.0001
Four	56.339	10.179	0.0001
Five	58.173	10.041	0.0001
Intercept	-3.066	9.508	0.748
Adjusted R-squared = 0.452, p= 0.0001			

Table 7. Multivariate Linear Regression Model of Institutional and Program Factors Associated with Change in the Institutional Hepatitis B Vaccination Rate at Follow-up in Iowa Hospitals (N=103).

Variable	ß	Standard Error	Significance
Baseline Institutional Vaccination Rate	-0.697	0.061	0.0001
Number of Registered Nurses	-0.028	0.014	0.050
Change in Proportion of Lab Workers	0.689	0.385	0.076
Vaccine Provided at Work site for Housekeepers	-5.510	2.964	0.066
Vaccine Provided at Meetings for Housekeepers	-5.680	2.866	0.050

Adjusted R^2 = 0.599, p=0.0001

Table 8. Logistic Regression Model of Factors Associated with Achievement of Institutional Levels of 90% of Workers Vaccinated at Follow-up Assessment in Iowa (N=102 hospitals)

Variable	ß	Standard Error	R	Significance
Transformed Baseline Vaccination Rate*	7.117	2.298	0.233	0.002
SMSA Location	-1.587	0.751	-.133	0.035
Encouragement of the Nursing Director	0.881	0.449	0.115	0.049
Constant	-6.080	1.992		0.002

-2 log likelihood 120.637, Model Chi-Square=19.350, 3 d.f., p= 0.002

NOTE: Using 50% cutoff, model sensitivity is 80.7%, specificity is 51.1% and accuracy is 67.7%

*Transformed by square root of institutional rate.

Table 9. Logistic Regression Model of Institutional Factors Associated with Achievement of 90% of Registered Nurses Vaccinated at Follow-up Assessment in Iowa and Virginia (N=133 hospitals)

Variable	β	Standard Error	Standardized Estimate	Odds Ratio	P-value
Intercept	-4.637	1.722			0.0071
# Outpatient Visits	-0.00002	6.09E-6	-0.536	1.00	0.0005
Invitation Letter	0.682	0.273	0.296	1.98	0.0125
Reminder to Complete Series	2.708	1.157	0.395	14.99	0.0193
HBV Leader Vaccination	1.969	1.186	0.287	7.16	0.0969

C statistic = 0.783 Hosmer-Lemeshow G.O.F. statistic = 1.69(8 d.f.), p=0.989).

Table 10. Logistic Regression Model of Institutional Factors Associated with Achievement of 90% of Licensed Practical Nurses and Nursing Assistants Vaccinated at Follow-up Assessment in Iowa and Virginia (N=133 hospitals)

Variable	β	Standard Error	Standardized Estimate	Odds Ratio	P-value
Intercept	-2.1112	0.5174	.	.	0.0001
Encouragement of all Leaders	1.3625	0.4888	0.3480	3.9060	0.0053
Provision of Vaccination at Worksite	1.1506	0.4882	0.2983	3.1600	0.0184
UP Compliance Monitored by Coworkers/Others	1.3437	0.4829	0.3508	3.8330	0.0054
Vaccination of all Leaders	0.9383	0.4503	0.2530	2.5560	0.0372

Table 11. Logistic Regression Model of Institutional Factors Associated with Achievement of 90% of Laboratory Workers Vaccinated at Follow-up Assessment in Iowa and Virginia (N=133 hospitals)

Variable	β	Standard Error	Standardized Estimate	Odds Ratio	P-value
Intercept	0.6438	0.6876	.	.	0.3491
Facility Complexity	-0.2624	0.1030	-0.3423	0.7690	0.0108
Provision of Vaccination at Worksite	0.9701	0.4626	0.2595	2.6380	0.0360
UP Compliance Monitored by Coworkers/Others	1.4899	0.4703	0.3950	4.4360	0.0015

Table 12. Comparison of worker characteristics, occupational exposures and preventive health measures use by hepatitis B vaccine status (N=898).

Characteristic	Vaccination Status					
	Unimmunized (n = 272)		Series Initiated (n = 626)		Series Completed (n = 482)	
Mean Age, (± S.D.), yrs.	40	± 11	37	± 10 [a]	37	± 10 [b]
Female, n (%)	162	(60)	414	(33) [c]	315	(66) [d]
Male, n (%)	107	(40)	204	(67)	160	(34)
Occupation (% in category)						
Physicians (Housestaff)	9	(11)	75	(89)	67	(80)
Physicians (Staff)	43	(46)	51	(54)	39	(42)
Registered Nurses	43	(15)	237	(85)	197	(70)
Licensed Practical Nurses	3	(20)	12	(80)	9	(60)
Nursing Assistants	14	(22)	49	(78)	32	(51)
Laboratory technologists	17	(29)	42	(71)	36	(61)
Housekeeping	19	(40)	28	(60)	11	(23)
Others	124	(49)	131	(51)	91	(36)
Work Site [e] (% in category)						
Outpatient clinic	65	(36)	118	(65)	94	(51)
Inpatient wards	61	(26)	177	(74)	134	(56)
Specialty ward/ICU	19	(18)	87	(82)	78	(74)
ER, Hemodialysis	3	(27)	8	(73)	7	(64)
Laboratory	34	(35)	63	(65)	49	(51)
Operating room	12	(18)	55	(82)	44	(66)
Other	72	(39)	111	(61)	70	(38)
# Blood Contacts/Past Yr., n						
Mean (95% C.I.)	7	(3, 10)	16	(10, 22) [f]	15	(8, 22) [g]
# Sharps Injuries/Past Yr., n						
Mean (95% C.I.)	0.8	(0.1, 1.6)	0.5	(0.4, 0.6)	0.5	(0.4, 0.7)
# Influenza Vaccinations/Past 3 Yrs. (% in category)						
None	189	(38)	308	(62)	226	(46)
1	32	(16)	164	(84)	129	(66)
2	23	(24)	74	(76)	59	(61)
3	28	(26)	79	(74)	67	(63)
Frequency of Seatbelt Use (% in category)						
Never	5	(71)	2	(29)	2	(29)
Occasional (<50%)	17	(39)	27	(61)	21	(48)
Frequent (≥50% to <100%)	30	(24)	97	(76)	67	(53)
Always	219	(31)	499	(70)	391	(55)

Note: ICU = intensive care unit, ER = emergency room. Percent in parentheses represents percent of total in each row. Due to rounding, % unimmunized and % initiating vaccine series may not total exactly 100%. The percent completing the series represents a subset of those initiating the series.

[a] $p<0.0001$, 2-sample t-test (CI_{95} for difference = 1.7, 4.8), compared to unimmunized.

[b] $p<0.0001$, 2-sample t-test (CI_{95} for difference = 1.8, 5.0), compared to unimmunized.

[c] $p=0.056$, Chi-square test, (OR=1.22, CI_{95} = 1.0, 1.5), females, compared to unimmunized.

[d] $p=0.096$, Chi-square test, (OR=1.18, CI_{95} = 1.0, 1.4), females, compared to unimmunized.

[e] Work site is the area of hospital in which the worker is primarily located.

[f] $p=0.011$, 2-sample t-test (CI_{95} for difference = -15.9, -2.0), compared to unimmunized.

[g] $p=0.037$, 2-sample t-test (CI_{95} for difference = -15.9, -0.5), compared to unimmunized.

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Table 13. Univariate correlates of hepatitis B vaccination among workers in the calibration set (N=599).

	Series initiation				Series completion			
Variable	OR	(95% C.I.)		P-Value	OR	(95% C.I.)		P-Value
Age [a]				0.0076				0.1172
30-39	0.70	0.37	1.31	0.2626	0.87	0.52	1.46	0.5969
40-49	0.48	0.27	0.84	0.0098	0.78	0.49	1.26	0.3115
>=50	0.40	0.22	0.71	0.0016	0.57	0.35	0.92	0.0222
Sex (Female) [b]	1.24	0.86	1.79	0.2503	1.08	0.77	1.52	0.652
Occupational Category [c]				<0.0001				<0.0001
Physicians (Housestaff)	7.51	2.35	24.02	0.0007	21.74	6.81	69.44	<0.0001
Physicians (Staff)	0.90	0.38	2.15	0.8176	4.43	1.51	13.03	0.0068
Nurses	4.36	1.92	9.88	0.0004	12.77	4.67	34.89	<0.0001
Nursing Assistants	2.04	0.76	5.48	0.1599	5.20	1.68	16.13	0.0043
Lab Techs, Others	0.99	0.46	2.13	0.9857	3.86	1.42	10.43	0.0079
Work Site [d]				0.0036				0.0002
Spec. Ward/ICU	1.96	1.04	3.70	0.0377	2.48	1.42	4.34	0.0014
Operating Room	3.79	1.47	9.76	0.0059	2.73	1.38	5.40	0.0039
Blood Exposures [e]				<0.0001				<0.0001
1-6	2.14	1.44	3.19	0.0002	2.83	1.94	4.13	<0.0001
7 or more	5.49	3.03	9.93	<0.0001	4.67	2.93	7.43	<0.0001
Sharps Injuries [e]				0.0003				0.0001
1	3.20	1.60	6.41	0.001	2.23	1.32	3.77	0.0027
2 or more	2.47	1.25	4.85	0.0088	2.63	1.49	4.66	0.0009
Influenza Vaccinations [f]				0.0001				0.0003
1	3.09	1.87	5.10	<0.0001	2.27	1.51	3.40	0.0001
2 or more	1.29	0.83	1.99	0.2591	1.53	1.02	2.31	0.0404
Seatbelt Use Frequency [g]				0.0823				0.1649
Frequent	2.62	1.12	6.12	0.0264	1.21	0.54	2.69	0.6473
Always	1.95	0.97	3.95	0.0626	1.67	0.83	3.37	0.1491

Note: OR = odds ratio, Spec. Ward = specialty ward (i.e. transplant, etc.), ICU = intensive care unit.

[a] Baseline strata = less than 30 years.

[b] Baseline strata = male.

[c] Baseline strata = housekeepers. Note: others includes students, research assistants, research scientists, etc.

[d] Baseline strata = Inpatient wards, outpatient clinics, emergency room, laboratory, hemodialysis.

[e] Baseline strata = none (in prior year).

[f] Baseline strata = none (in prior three years).

[g] Baseline strata = occasionally (< 50%) or never.

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Table 14A. Reasons for vaccine refusal.

Factor	Eigen Value	% Variance Explained
Threat of Disease	5.3	35.0
Knowledge of Disease	1.4	9.4
Access to Care	1.2	7.8
Risk Denial	1.1	7.1
Social Influence	1.0	6.7

Table 14B. Reasons for vaccine acceptance.

Factor	Eigen Value	% Variance Explained
Social Influence	5.0	38.6
Threat of Disease	1.1	8.8
Knowledge of Disease	1.0	7.4

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Table 15. Final logistic models of predictors of hepatitis B vaccination in the entire sample (N=898).

	Series Initiation				Series Completion			
Variable	OR	CI95		P-Value	OR	CI95		P-Value
Age, yrs.	0.98	0.96	0.997	0.0201				
Occupation [a]				<0.0001				<0.0001
Physicians (Housestaff)	2.89	1.07	7.86	0.0371	8.04	3.22	20.04	<0.0001
Physicians (Staff)	0.51	0.23	1.13	0.0915	1.46	0.63	3.39	0.3789
Nurses	2.07	0.99	4.32	0.0536	4.93	2.26	10.75	0.0001
Nursing Assistants	1.67	0.66	4.25	0.2806	2.87	1.18	6.97	0.02
Lab Techs, Others	0.64	0.32	1.26	0.1954	2.09	0.98	4.45	0.0553
Blood Exposure [b]				<0.0001				<0.0001
1-6	2.40	1.64	3.51	<0.0001	2.35	1.69	3.28	<0.0001
>=7	3.48	2.05	5.93	<0.0001	3.11	2.02	4.78	<0.0001
Influenza Vaccinations [c]				<0.0001				<0.0001
1	3.25	2.01	5.27	<0.0001	2.23	1.53	3.25	<0.0001
2 or more	2.23	1.46	3.40	0.0002	2.27	1.57	3.29	<0.0001
Constant		4.50	18.75	<0.0001		1.15	1.78	0.0012

[a] Odds of vaccination per year of age.

[b] Baseline strata = housekeepers, others.

[c] Baseline strata = none (in prior year).

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APPENDICES

Appendix 1. Relative Ranking of Reasons for Not Receiving the Vaccine and Rotated Factor Matrix

Reason	Mean Score * N=272	Factor 1 Threat of Disease	Factor 2 Knowledge of Disease	Factor 3 Access to Care	Factor 4 Risk Denial	Factor 5 Social Influence
Concern about possible jaundice due to vaccination	2.2	.80901	.31464	.02881	.04333	.05757
Concern about possible AIDS due to vaccination	1.6	.78146	.06823	.02038	-.02195	.06547
Concern about side effects of vaccine	2.8	.74249	.20226	.27680	.04380	-.10097
Unconvinced of efficacy of vaccine	1.7	.61457	.07492	.31257	.27712	.17151
Behavior of someone I respect (Role model)	1.2	.42184	.04876	.33804	.35363	.38448
Have not received letter of invitation	2.2	-.01509	.82219	.18924	-.00086	.02327
Insufficient information about the vaccine	2.6	.40811	.71946	.12761	.07295	-.02879
Insufficient information about the disease	1.9	.43210	.68774	.10637	.19715	.15591
Unable to afford the vaccine	1.4	.21847	.38883	.21945	.35859	.34543
Too busy/never enough time	2.2	.13634	.05680	.88410	-.03736	.01480
Difficulty in obtaining the vaccine	1.8	.10852	.32791	.74149	.09767	.17539
Fear of needles/injections/pain	1.7	.27481	.25831	.40834	.32155	-.00800
Not at increased risk	3.0	.00648	.06105	-.00145	.91563	-.02767
Prior history of hepatitis	1.5	-.05977	-.05395	-.03588	-.14136	.85488
Physician recommendation	1.3	.17402	.24352	.23780	.28500	.54885

* Likert scale items ranged from "Not Important" (1) to "Very Important" (7).

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Appendix 2. Relative Ranking of Reasons for Receiving the Vaccine and Rotated Factor Matrix

Reason	Mean Score * N=626	Factor 1 Social Influence	Factor 2 Threat of Disease	Factor 3 Knowledge of Disease
Recommendation of friend	2.4	.77789	.13180	.09292
Recommendation of spouse/significant other	2.2	.71024	.24278	.11965
Recommendation of superior/supervisor	3.3	.60284	.03281	.36814
Behavior of someone I respect (Role model)	2.4	.56860	.45710	.21259
Recommendation of physician	3.1	.56624	.38169	.05810
Provide care for hepatitis patients	4.0	-.00916	.72767	.21027
Previous needlestick/sharps injury	3.0	.15249	.72158	-.01923
Possible restriction from pt. care if infected	2.8	.35486	.62683	.25614
Concern about professional liability	2.8	.39367	.59035	.22584
Friend/coworker developed occupational hepatitis	2.2	.28262	.58031	.12744
Information letter from employer	3.0	.20080	.06261	.74791
Information obtained from professional sources	5.1	.04219	.23497	.70803
Information obtained from general media	2.5	.43910	.21027	.52002

* Likert scale items ranged from "Not Important" (1) to "Very Important" (7).

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REFERENCES

1. OSHA. Bloodborne Pathogens Rule. Fed Register. 1991;56(235):64175-82.
2. U.S.Department of Health and Human Services. Healthy People 2000: National health promotion and disease prevention objectives. Washington, D.C.: U.S. Government Printing Office; 1991:1-154.
3. Shapiro CN, Margolis HS. Hepatitis B epidemiology and prevention. Epidemiol Rev. 1990;12:221-7.
4. Hollinger FB. Comprehensive control (or elimination) of hepatitis B virus transmission in the United States. [24 refs]. Gut. 1996;38 Suppl 2:S24-S30
5. Hlady WG, Hopkins RS, Ogilby TE, Allen ST. Patient-to-patient transmission of hepatitis B in a dermatology practice. Am J Public Health. 1993;83:1689-93.
6. Hadler SC, Doto IL, Maynard JE, et al. Occupational risk of hepatitis B in hospital workers. Infect Control. 1985;6:24-31.
7. Hicks CG, Hargiss CO, Harris JR. Prevalence survey for hepatitis B in high-risk university hospital employees. Am J Infect Control. 1985;13:1-6.
8. Doebbeling BN, Wenzel RP. Nosocomial viral hepatitis. In: Mandell GL, Douglas RG, Jr., Bennett JE, eds. Principles and Practice of Infectious Diseases. 3 ed. New York: Churchill Livingstone; 1990:2215-21.
9. Stroffolini T, Palumbo F, Galanti C, et al. Hepatitis B in health workers in Italy. Public Health. 1994;108:433-7.
10. Weber DJ, Hoffmann KK, Rutala WA. Management of the health care worker infected with human immunodeficiency virus: lessons from nosocomial transmission of hepatitis B virus. Infect Control Hosp Epidemiol. 1991;12(10):625-30.
11. Gibas A, Blewett DR, Schoenfeld DA, Dienstag JL. Prevalence and incidence of viral hepatitis in health workers in the prehepatitis B vaccination era. Am J Epidemiol. 1992;136(5):603-10.
12. Centers for Disease Control. Protection against viral hepatitis: recommendations of the Immunizations Practices Advisory Committee (ACIP). M.M.W.R. 1990;39 (No. RR-2):1-26.
13. Beekmann SE, Doebbeling BN. Frontiers of occupational health. New vaccines, new prophylactic regimens, and management of the HIV-infected worker. Infect Dis.Clin.North Am. 1997;11:313-29.
14. Doebbeling BN, Wenzel RP. Nosocomial viral hepatitis and infections transmitted by blood and blood products. In: Mandell GL, Bennett DL, Dolin R, eds. Principles and Practice of Infectious Diseases. 4th ed. New York: Churchill Livingstone, Inc.; 1995:2616-32.
15. Howard G. Hepatitis B and the employer's duty to vaccinate. Occup.Health (Lond.). 1996;48:284-6.
16. Iwarson s. Strategies for immunization against hepatitis B in western Europe. Vaccine. 1993;11 Suppl 1:S18-S20
17. Tokars JI, Alter MJ, Favero MS, Moyer LA, Bland LA. National surveillance of hemodialysis associated diseases in the United States, 1990. ASAIO.Journal. 1993;39:71-80.
18. Kinnersley P. Attitudes of general practitioners towards their vaccination against hepatitis B. Br Med J. 1990;300(6719):238
19. Burden AD, Whorwell PJ. Poor uptake of hepatitis B immunization amongst hospital-based health care staff. Postgrad Med J. 1991;67(785):256-8.
20. Schiff ER, de Medina MD, Kline SN, et al. Veterans Administration cooperative study on hepatitis and dentistry. JADA. 1986;113:390-6.
21. Murata PJ, Young LC. Physicians' attitudes and behaviors regarding hepatitis B immunization. J Fam Pract. 1993;36:163-8.
22. Shanks NJ, Rowlands DF. Personal immunization against hepatitis B. J R Soc Med. 1993;86:154-5.

23. Thomas DL, Factor SH, Kelen GD, Washington AS, Taylor E, Quinn TC. Viral hepatitis in health care personnel at The Johns Hopkins Hospital: the seroprevalence of and risk factors for hepatitis B virus and hepatitis C virus infection. Arch.Intern.Med. 1993;153:1705-1712.
24. Israsena S, Kamolratanakul P, Sakulramrung R. Factors influencing acceptance of hepatitis B vaccination by hospital personnel in an area hyperendemic for hepatitis B. Am J Gastroenterol. 1992;87:1807-9.
25. Williams S, Gooch C, Cockcroft A. Hepatitis B immunization and exposure to blood among surgical staff. Br J Surg. 1993;80:714-6.
26. Alerany C, Zara C, Grifell E, Guarga A. [Vaccination against hepatitis B in health workers and other staff in Barcelona]. [Spanish]. Aten.Primaria. 1993;12:480-6.
27. Barie PS, Dellinger EP, Dougherty SH, Fink MP. Assessment of hepatitis B virus immunization status among North American surgeons. Arch Surg. 1994;129:27-31.
28. Coates RA, Halliday ML, Rankin JG, et al. Immunogenicity and safety of a yeast-derived recombinant DNA hepatitis B vaccine in health care workers. In: Zuckerman AJ, ed. Viral Hepatitis and Liver Disease. New York: Alan R. Liss; 1988:1032-42.
29. Andre FE. Summary of safety and efficacy data on a yeast-derived hepatitis B vaccine. Am J Med. 1989;87(3A):14S-20S.
30. McMahon BJ, Helminiak C, Wainwright RB, Bulkow L, Trimble BA, Wainwright K. Frequency of adverse reactions to hepatitis B vaccine in 43,618 persons. Am J Med. 1992;92(3):254-6.
31. Dentico P, Buongiorno R, Volpe A, Zavoianni A, Pastore G, Schiraldi O. Long-term immunogenicity safety and efficacy of a recombinant hepatitis B vaccine in healthy adults. Eur J Epidemiol. 1992;8(5):650-5.
32. Anonymous. Expanded programme on immunization (EPI). Lack of evidence that hepatitis B vaccine causes multiple sclerosis. Wkly.Epidemiol.Rec. 1997;72:149-52.
33. Alter MJ, Hadler SC, Margolis HS, et al. The changing epidemiology of hepatitis B in the United States. Need for alternative vaccination strategies. JAMA. 1990;263(9):1218-22.
34. Dal-Re R, Gonzalez A, Ramirez V, Ballesteros J, del Romero J, Bru F. Compliance with immunization against hepatitis B. A pragmatic study in sexually transmitted disease clinics. Vaccine. 1995;13:163-7.
35. Scapa E, Karpuch J, Waron M, et al. Attitude of hospital personnel toward hepatitis B vaccination. Am J Gastroenterol. 1989;84:400-2.
36. Crossley KB, Gerding DN, Petzel RA. Acceptance of hepatitis B vaccine by hospital personnel. Infect Control. 1985;6:147-9.
37. Berridge DC, Galea MH, Evans DF, Pugh S, Hopkinson BR, Makin GS. Hepatitis B immunization in vascular surgeons. Br J Surg. 1990;77:585-6.
38. Wenzel RP, Osterman CA, Townsend TR, et al. Development of a statewide program for surveillance and reporting of hospital-acquired infections. J Infect Dis. 1979;140:741-6.
39. Diekema DJ, Ferguson KJ, Doebbeling BN. Motivation for hepatitis B vaccine acceptance among medical and physician assistant students. J Gen Intern Med. 1995;10:1-6.
40. Hosmer DW, Lemeshow S. Applied Logistic Regression. 1 ed. New York: John Wiley & Sons; 1989.
41. Hosmer DW, Taber S, Lemeshow S. The importance of assessing the fit of logistic regression models: A case study. Am J Public Health. 1991;81:1630-5.
42. Lemeshow S, Hosmer DW, Jr. A review of goodness of fit statistics for use in the development of logistic regression models. Am J Epidemiol. 1982;115:92-106.
43. Harrell FE, Jr, Califf RM, Pryor DB, Rosati RA. Regression modeling strategies for improved prognostic prediction. Stat.Med. 1984;2:143-53.
44. Cummings KM, Becker MH, Maile MC. Bringing the models together: an empirical approach to combining variables used to explain health actions. J Behav Med. 1980;3(2):123-45.

45. Kleinbaum DG, Kupper LL, Morgenstern H. Epidemiologic Research. Principles and Quantitative Methods. New York: Van Nostrand Reinhold; 1982:

46. Doebbeling BN, Rohrer JE, Kohout FJ. Hepatitis B vaccine acceptance pre- and post-implementation of OSHA's Bloodborne Pathogens Rule. 34th Annual ICAAC Conference. 1994;139-139.[Abstract]

47. Favero MS, Harwood S, Iwarson S. Strategies for control of hepatitis in health-care workers. In: Hollinger FB, ed. Viral Hepatitis and Liver Disease. Baltimore: Williams and Wilkins; 1991:827-31.

48. Osterholm MT, Garayalde SM. Clinical viral hepatitis B among Minnesota hospital personnel: results of a ten-year statewide survey. JAMA. 1985;254:3207-12.

49. Alter MJ, Favero MS, Maynard JE. Impact of infection control strategies on the incidence of dialysis-associated hepatitis in the United States. J Infect Dis. 1986;153:1149

50. Tong MJ, Howard AM, Schatz GC, et al. A hepatitis B vaccination program in a community teaching hospital. Infect Control. 1987;8(3):102-7.

51. Stephenne J. Recombinant versus plasma-derived hepatitis B vaccines: issues of safety, immunogenicity and cost-effectiveness. Vaccine. 1988;6:299-303.

52. Aday L, Andersen R. A framework for the study of access to medical care. H Svcs Research. 1974;9:208-20.

53. Fahey BJ, Koziol DE, Banks SM, Henderson DK. Frequency of nonparenteral occupational exposures to blood and body fluids before and after universal precautions training. Am J Med. 1991;90:145-53.

54. Sellors J, Pickard L, Mahony JB, et al. Understanding and enhancing compliance with the second dose of hepatitis B vaccine: a cohort analysis and a randomized controlled trial. CMAJ. 1997;157:143-8.

55. Doebbeling BN, Li N. Hepatitis B vaccination: independent predictors of health care worker compliance. Program and Abstracts of the 32nd ICAAC. 1992;Abstr. #1193[Abstract]

56. Hersey JC, Collins JW, Gershon R, Owen B. Methodologic issues in intervention research--health care. Am J Ind.Med. 1996;29:412-7.

57. LaMontagne AD, Needleman C. Overcoming practical challenges in intervention research in occupational health and safety. Am J Ind.Med. 1996;29:367-72.

PUBLICATIONS

Abstracts:

Hepatitis B Vaccine Acceptance:

1) Diekema DJ, Ferguson KJ, **Doebbeling BN**. Motivation for compliance with hepatitis B vaccination among medical students. Program and Abstracts of the 4th Annual SHEA Meeting, New Orleans, LA, Abstract # 28, March, 1994.

2) **Doebbeling BN**, Rohrer JE, Kohout FJ. Institutional predictors of hepatitis B vaccination rates: A statewide study of health care workers. The 11th Annual Association for Health Services Research Meeting, San Diego, CA, Abstract # 178, P. 146, June, 1994.

3) **Doebbeling BN**, Rohrer JE. Acceptance of hepatitis B vaccine: The Iowa Statewide Surveillance System (ISSS) Study. 3rd International Conference of the Hospital Infection Society, London, United Kingdom, Abstract #P245, Page 5-90, September, 1994.

4) **Doebbeling BN**, Rohrer JE, Kohout FJ. Hepatitis B vaccine acceptance pre- and post-implementation of OSHA's Bloodborne Pathogens Rule. Abstracts of the 34th Annual ICAAC Meeting, Abstract # J136, Page 139, Orlando, FL, October, 1994.

5) Diekema DJ, Albanese MA, Densen P, **Doebbeling BN**. Protecting medical students from infection: A survey of United States medical schools. Abstracts of the 35th Annual ICAAC Meeting, Abstract # J102, P. 275, San Francisco, CA, September, 1995.

6) **Doebbeling BN**, Rohrer JE, Beekmann SE, Kohout FJ. The impact of OSHA's Bloodborne Pathogen's Rule on institutional hepatitis B vaccination rates. 13th Annual Meeting of the Association for Health Services Research, Atlanta, GA, June 9-11, 1996.

7) **Doebbeling BN**, Rohrer JE, McCoy K. Achieving institutional levels of hepatitis B vaccination in the health care workforce according to national guidelines. 15th Annual Meeting of the Association for Health Services Research, (Submitted), Washington, D.C., June 21-23, 1998.

Universal Precautions:

1) Schmid MS, Garvin ML, Rasley DA, Blake SM, Philibert I, Yank T, **Doebbeling BN**. Bloodborne pathogens training: Evaluation of the effect of required training and documented informed refusal. Program and Abstracts of the 3rd Annual SHEA Meeting, Chicago, IL, Abstract #85, April, 1993.

2) Voss A, Leick CA, Torremorell Y, Downs DD, Wenzel RP, **Doebbeling BN**. Handwashing agent use: A possible marker for nosocomial infections. Program and Abstracts of the 33rd Interscience Conference on Antimicrobial Agents and Chemotherapy Meeting (ICAAC), New Orleans, LA, Abstract # 59, p. 130, October, 1993.

3) Diekema DJ, Albanese MA, Schuldt SS, **Doebbeling BN**. Long-term impact of universal precautions training on knowledge, compliance, attitudes and exposures. Program and Abstracts of the 4th Annual SHEA Meeting, New Orleans, LA, Abstract # 27, March, 1994.

4) Diekema DJ, Albanese MA, Schuldt SS, **Doebbeling BN**. Universal precautions training of preclinical students: Relationship of knowledge to exposure rates during clinical training. Abstracts of the 34th Annual ICAAC Meeting, Abstract # J137, Page 140, Orlando, FL, October, 1994.

5) Schuldt SS, Diekema DJ, Albanese MA, **Doebbeling BN**. Universal precautions training of preclinical students: Impact on knowledge, attitudes and behavior. The 19th Annual Session of the Innovations in Medical Education Exhibits, 105th Annual Meeting of the Association of American Medical Colleges, p. 14, Boston, MA, November, 1994.

6) Beekmann SE, Woodward T, Brown C, Schuldt S, **Doebbeling BN**. Relationship of universal precautions knowledge to sharps injury risk: A prospective cohort study. Abstracts of the 36th Annual ICAAC Meeting, Abstract J139, September 18, 1996.

Percutaneous Injury:

1) Edmond MB, Clark TG, **Doebbeling BN**. Independent risk factors for multiple percutaneous injuries. Midwest AFCR/CSCR Meeting, Chicago, IL, Clinical Research 41(3):646A, 1993.

2) Edmond MB, Clark TG, Askelson DL, **Doebbeling BN**. Determinants of recurrent percutaneous injuries reported by health care workers. Program and Abstracts of the 4th Annual SHEA Meeting, New Orleans, LA, Abstract # 26, March, 1994.

3) **Doebbeling BN**, Garvin ML, Diekema DJ, Weismann DN. Evaluation of interventions to reduce percutaneous injuries in health care workers. 3rd International Conference of the Hospital Infection Society, London, United Kingdom, Abstract # F6/7, Page 3-18, September, 1994.

4) Diekema DJ, Garvin ML, Weismann DN, Rasley DA, Streed S, **Doebbeling BN**. The impact of interventions to reduce sharps injuries: A decade of experience. Abstracts of the 34th Annual ICAAC Meeting, Abstract # J135, Page 139, Orlando, FL, October, 1994.

5) **Doebbeling BN**, Ringold DM, Korman KT, Dawson JD, Torner JC. Evaluation of the efficacy of measures recommended to prevent percutaneous injuries: A cohort study. Abstracts of the 35th Annual ICAAC Meeting, Abstract # J101, Page 275, San Francisco, CA, September, 1995.

6) **Doebbeling BN**, Beekmann SE, Ringold D. Multivariate models of institutional and work-site related risk factors for sharps injury. Abstracts of the 36th Annual ICAAC Meeting, Abstract #J140, September 18, 1996.

7) McCoy K, Beekmann SE, Vaughn T, Ferguson K, Torner J, **Doebbeling BN**. Factors associated with adequacy of standard precautions training: Results of two statewide surveys. Abstracts of the 8th Annual Meeting of the Society for Healthcare Epidemiology of America, (Submitted), April, 1998.

8) Beekmann SE, McCoy K, Vaughn T, **Doebbeling BN**. Standard precautions programs and infection control resources available in smaller vs. larger healthcare facilities: Results of two statewide surveys. Abstracts of the 8th Annual Meeting of the Society for Healthcare Epidemiology of America, (Submitted), April, 1998.

Book Chapters:

1) **Doebbeling BN**, Wenzel RP. Nosocomial viral hepatitis and infections transmitted by blood and blood products. In: Principles and Practice of Infectious Diseases, (eds. GL Mandell, JE Bennett, R Dolin), New York: Churchill Livingstone, Inc., 4th Edition, pp 2616-2632, 1995.

2) **Doebbeling BN**. Percutaneous injury: Risks and management. In: D. Schlossberg (Ed): Current Therapy of Infectious Disease. St. Louis, Mosby-Year Book, Inc., 1996:332-335.

3) **Doebbeling BN**. Protecting the healthcare worker from infection and injury. In: RP Wenzel (Ed): *Prevention and Control of Nosocomial Infections*. Baltimore, Maryland: Williams & Wilkins, 3rd Edition, 1997:397-435.

4) Diekema DJ, **Doebbeling BN**. Employee health and infection control. In: LA Herwaldt (ed): *A Practical Handbook for the Hospital Epidemiologist*. Nashville, TN: SHEA, 1st Edition 1997 (In Press).

Journal Articles:

1) Diekema DJ, Ferguson KJ, **Doebbeling BN**. Motivation for hepatitis B vaccine acceptance among medical and physician assistant students. *J Gen Intern Med* 10:1-6, 1995.

2) Diekema DJ, Schuldt SS, Albanese MA, **Doebbeling BN**. Universal precautions training of preclinical students: Impact on knowledge, attitudes and compliance. *Prev Med* 24:580-585, 1995.

3) Diekema DJ, **Doebbeling BN**. Employee health and infection control. *Infect Control Hosp Epidemiol* 1995;16:292-301.

4) **Doebbeling BN**, Ferguson KJ, Kohout FJ. Predictors of hepatitis B vaccine acceptance in health care workers. *Medical Care* 34:58-72, 1996.

5) Diekema DJ, Albanese MA, Schuldt SS, **Doebbeling BN**. Blood and body fluid exposures during clinical training: Relation to universal precautions knowledge. *J Gen Intern Med* 11:109-111, 1996.

6) Diekema DJ, Albanese MA, Densen P, **Doebbeling BN**. Student health policies of U.S. medical schools. *Acad Med* 71:1090-1092, 1996.

7) Beekmann SE, **Doebbeling BN**. Frontiers of occupational health: New vaccines, new prophylactic regimens, and management of the HIV-infected worker. In: Weber DJ and Rutala WA (Eds): Nosocomial Infections. *Infectious Disease Clinics of North America*, 1997;11(2) 313-329.

8) Beekmann SE, **Doebbeling BN**. Vaccines for health care workers. In: Panlilio AL and Cardo D (Eds): Prevention Strategies for Health Care Workers. *Bailliere's Clinical Infectious Diseases*, (In preparation), 1997.

Manuscripts in Preparation:

1) **Doebbeling BN**, Rohrer JE, West CP. The impact of OSHA's Bloodborne Pathogens Rule on institutional hepatitis B vaccination rates among health care workers: A statewide study. (In preparation), 1997.

2) **Doebbeling BN**, Rohrer JE, McCoy K. Institutional organizational and program characteristics of effective hepatitis B vaccine delivery to community health care workers. (In preparation), 1997.

3) **Doebbeling BN**, Polzer J, Beekmann SE, Ringold DM, Torner JC. Evaluation of the effectiveness of recommended measures to prevent percutaneous injury. (In preparation), 1997.

Inventions & Patents:

Not applicable.