MILITARY MEDICINE, 165, 4:309, 2000

The Cost-Effectiveness of Varicella Screening and Vaccination in U.S. Army Recruits

Guarantor: M. René Howell, MA*
Contributors: M. René Howell, MA*; Terrence Lee, MPH†; Charlotte A. Gaydos, MPH DrPH*; Roberto N. Nang, MC USA†

Varicella outbreaks in the U.S. Army disrupt training, reduce readiness, and represent substantial costs. Vaccination of susceptible individuals may be cost-effective. We conducted a cost-effectiveness analysis comparing screening of all incoming recruits and vaccination of susceptible individuals at either initial entry training (IET) or medical entrance processing station (MEPS), universal vaccination at IET, and no intervention. Primary health outcomes included the number of varicella cases prevented during the 8-week initial training period. The varicella hospitalization rate was 21.6 per 10,000 per year. In 100,000 recruits, 36 cases of varicella are expected at a cost of $181,000 in the absence of an intervention. Screening at IET would prevent 4 cases but would cost an additional $3,255,000 more than no intervention. Screening at MEPS would prevent 3 cases and save $521,000 per case prevented during the IET but would cost $2,734,000 more than no intervention. Universal vaccination would prevent 2 cases but would cost $15,858,000 more than MEPS screening and $18,592,000 more than no intervention. These results are robust. Cost per case of varicella prevented ranged from $390,000 to $7.9 million. Scarce prevention resources could be more cost-effectively allocated to other prevention programs.

Varicella infections represent significant morbidity in young adults.[1] Clinical disease necessitates isolation from susceptible individuals and observation for high fever.[1] The Centers for Disease Control estimates 10,000 hospitalizations for varicella each year, with a complication rate of 8 per 1,000 hospitalizations and a fatality rate of 2.7 per 100,000 hospitalizations.[2,3]

Seroprevalence studies conducted in the late 1980s found that 8.8% of new Army recruits lacked sufficient antibody titers to provide protection against varicella disease.[4] Varicella is transmitted during part of the subclinical phase of infection; thus, infected individuals can transmit varicella to a large number of individuals before infection is detected. Between 1990 and 1997, 3,705 cases of varicella disease were reported and resulted in hospitalization in the Army.[5] The overall incidence for this period was 87.9 per 100,000 soldiers per year. Other military services report varying incidence rates of varicella.[6,7]

Varicella outbreaks in the U.S. military can disrupt training schedules, reduce readiness, and significantly increase medical care costs. Consequently, implementation of a vaccine program to protect against varicella disease has been suggested as a potential strategy to avert the costs and morbidity associated with varicella disease during initial entry training (IET).[1,3,5,6]

To estimate the health and economic consequences of different prevention strategies against varicella disease in newly enlisted Army recruits, we conducted a cost-effectiveness analysis and compared two different screening and vaccination policies and a no-intervention policy. Interventional strategies were analyzed as they would be implemented under current training and medical care standard operating procedures. This analysis evaluates vaccine cost-effectiveness in a training environment, not only in terms of medical costs but also in terms of lost productivity in training to the military.

Methodology

Model Characteristics

A computer-based, decision analytic probability model (DATA 3.0 TreeAge, Williamstown, MA) estimated the cost-effectiveness of four prevention strategies: (1) antibody screening at the military entrance processing station (MEPS) and vaccination at the IET reception battalion for individuals found to be susceptible; (2) both antibody screening and vaccination at IET for individuals found to be susceptible; (3) vaccination for all incoming recruits at IET; and (4) no vaccination.

Morbidity rates and total costs were estimated. The outcomes associated with each policy were measured as the expected vaccination costs, the direct and indirect medical and military training costs, the associated number of varicella cases (International Classification of Diseases, Ninth Revision [ICD-9] code 052.9) assessed as hospitalizations prevented, and the associated number of varicella complications (ICD-9 codes 052.1, 052.7, and 052.8) assessed as hospitalizations prevented. Adverse events, including fever and rash resembling varicella disease, have been reported with use of the vaccine (Varivax package insert, Merck and Co., West Point, PA). These events would require hospitalization during the military IET period. Consequently, these events were included in the model as non-varicella morbidity, and the costs of required treatment were considered within the vaccine cost.

Reference case cost and probability parameters, as well as the ranges used in sensitivity analyses, were based on published studies, military surveillance data for varicella-related hospitalizations, training protocol records, accounting and financial reports, reimbursement databases, and the expert opinions of military preventive medicine clinicians.

Approximately 99,900 new recruits enter the Army each year

*Infectious Diseases Division, The Johns Hopkins University, Baltimore, MD.
†U.S. Army Center for Health Promotion and Preventive Medicine, Aberdeen Proving Ground, MD.

The opinions presented are those of the authors and do not necessarily reflect the opinions of The Johns Hopkins University, the U.S. Department of Defense, or the U.S. Army.

Reprint requests: René Howell, MA, The Johns Hopkins University, Division of Infectious Diseases, Ross Research Building, Room 1159, 720 Rutland Avenue, Baltimore, MD 21205. Fax: 410-614-9775; e-mail: mrh@welchlink.welch.jhu.edu.

This manuscript was received for review in June 1999. The revised manuscript was accepted for publication in October 1999.

(U.S. Army Training and Doctrine Command [TRADOC], Fort Monroe, VA, 1998). The results of the final model were extrapolated to 100,000 recruits from a 1-year analytic horizon for 8 weeks of basic training per individual. The cost figures presented were rounded to the nearest $1,000, and morbidity estimates were rounded to the nearest case.

Event Probability and Cost Estimates

All costs and cost ranges were calculated in 1996 U.S. dollars using a 5% annual discount rate (Table I). There are several screening assays available. The reference case modeled use of the ELISA-STAT antibody test, with reported sensitivity of 86.1%, specificity of 98.6%, and a military cost of $11.24 per test (including clinic and pathology personnel, supplies, specimen transportation, and assay cost [LTC Hendrix and MAJ Harms, Fort Jackson, South Carolina, and LTC Wilson, LTC McAfee, and SSG Sondgeroth, Fort Leonard Wood, Missouri, personal communication, 1998]).[4,8] The timing of the administration of the first dose of the vaccine will affect the prevention potential of the vaccine as a result of delayed onset of protective antibody levels. Consequently, two sites for implementation of the screening component were considered, the MEPS and the reception battalion of IET. If screening were implemented at the MEPS, the vaccine could be administered to susceptible recruits within 48 hours of arrival at IET. In this manner, protective antibodies would develop by week 4 (Varivax package insert). Assuming no antibody formation until after week 4,[9-11] individuals exposed to varicella would develop varicella disease until week 4. Considering an average 2-week incubation period, clinical disease would occur only after week 6. If screening were conducted at IET, administration of vaccine would be delayed as a consequence of screening test processing, and clinical disease would not be prevented until after week 7. In the universal vaccination strategy (similar to the MEPS screening strategy),

TABLE I

RISK OF EVENTS AND COST ESTIMATES MODELED IN THE REFERENCE CASE (ALL COSTS ARE IN 1996 DOLLARS USING A 3% DISCOUNT RATE)

Variable	Event Probability	Cost	Source
Varicella Hospitalization Rate (IET, 8 weeks)	21.6/10,000 person-years		TRADOC, MEDCOM
1 month	34.9%		MEDCOM
2 months	65.1%		MEDCOM
Antibody screening (ELISA-Stat)		$11.24 (range, $7–$14)	LTC Hendrix, Fort Jackson, SC, and SSG Sondgeroth, Fort Leonard Wood, MO, 1998
Sensitivity	86.1%		2, 4
Specificity	98.6%		2, 4
Observed susceptible	8.8% (7.4%–10.3%)		4
Vaccine effectiveness		$29.83[a]	Varivax insert and SSG Sondgeroth, Fort Leonard Wood, MO
Dose 1	75%		
Dose 2 (cumulative	99.7%		
Adverse events			
Fever (1 minimal care ward day)		$105	Varivax insert, MEDCOM, 12
Dose 1	4.7%		
Dose 2	8.6%		
Rash (1 inpatient bed day)		$659	Varivax insert and MEDCOM
Dose 1	5.5%		
Dose 2	0.9%		
Outpatient visit (TMC)		$58	12
Sequelae costs (conditional on varicella disease)			
Varicella inpatient (5.4 inpatient bed days)	100%	$659/day (range, $659–$1,101)	MEDCOM
Total		$3,558.60	
Death with uncomplicated varicella	3.1/10,000	$1,000,000	14
Complications (7.3 inpatient bed days)	33.3/10,000	$672/day (range, $672–$1152)	16, MEDCOM
Total		$4,905.60	
Death with complicated varicella	1,000/10,000	$1,000,000	14
Training day		$139	TRADOC

[a] $29.75 cost and $0.08 supplies; $1.17 administration cost added for MEPS strategy; $58 added for clinic visit for IET strategy.

recruits would receive the vaccine within 48 hours of arrival, and first-dose protection would be achieved after week 4 and disease would be prevented after week 6.

The varicella vaccine Varivax is a two-dose, live attenuated varicella-zoster virus. Each dose costs the military $29.75 for the vaccine. Supplies to administer the vaccine (e.g., hypodermic jet injection apparatus) would cost an additional $.08 per dose (SSG Sondgeroth, Fort Leonard Wood, Missouri, personal communication, 1998), and administration itself would cost $1.17, for a total vaccine cost of $31. Under the vaccinate-all and the MEPS screening strategies, the first dose of varicella vaccine would be administered during in-processing as part of a vaccination series. Consequently, minimal time would be required for the first dose of vaccine, for a cost of $1.17 (median cost for a specialist E-3) (MAJ Hewitson, Fort Leonard Wood, Missouri, personal communication, 1999). However, the second dose of the vaccine would require a clinic visit, at a cost of $58 (Troop Medical Clinic [TMC], Fort Jackson, South Carolina).[12] The IET strategy would require a clinic visit for the first and the second dose. The vaccine is effective in causing development of protective antibodies against varicella disease in 75% of vaccinated individuals after week 4 and in 99.7% of individuals after the second dose (Varivax package insert).

Morbidity and Cost-of-Illness Estimates

The most current morbidity data were used. In 1997, approximately 99,930 recruits entered IET (the first 8 weeks of training), accounting for 16,655 person-years (TRADOC). During this period, 241 cases of varicella were reported, 36 of which occurred during IET (TRADOC, U.S. Army Medical Command [MEDCOM] Headquarters, Fort Sam Houston, Texas, 1998). All individuals with varicella during IET were hospitalized, resulting in a varicella hospitalization rate of 21.6 per 10,000 recruit person-years.[13] A seroprevalence study by Kelley et al. showed that approximately 8.8% of new recruits lack protective antibodies.[4] We used this seroprevalence to calculate an incidence rate of 4.1 per 1,000 susceptible recruit person-years. Approximately 35% of the cases will occur within 4 weeks of training. Vaccination provides no protection for these individuals because it is likely that they will not have developed protective antibodies during those 4 weeks. Additionally, considering a 2-week incubation period, varicella disease occuring in weeks 5 and 6, contracted during week 4, also would not be prevented. Vaccination would prevent clinical disease only during weeks 7 and 8 if vaccine is administered within 48 hours of arrival at IET. Assuming an even distribution of cases during the second month of IET, 32.6% of all cases occurring during IET would be affected by the MEPS screen strategy and 16.4% of all cases occurring during IET would be affected by the IET screen strategy. The vaccinate-all strategy would affect the same 32.6% as the MEPS screen strategy.

The vaccine is reportedly associated with mild to moderate adverse reactions, including fever, injection site complaints, and localized or generalized varicella rash (Varivax package insert). Adverse events included in the model were limited to fever and generalized varicella-like rash. Other complaints are mild in nature and most likely would not require clinical care. Of vaccinated individuals, 10.2% would experience a fever greater than 100°F. These individuals would require a 1-day inpatient stay in a minimal care unit at a cost of $105 per day (MEDCOM, 1997).[12] Additionally, 5.5% of all vaccinated individuals would experience a generalized varicella-like rash. This presentation, albeit milder, closely imitates natural varicella disease, and affected individuals would be hospitalized for 1 day of observation at a cost of $659 (MEDCOM, 1997). Additionally, adverse events associated with vaccination would incur one outpatient visit at a cost of $58 per visit to the TMC.[12] To avoid repeated consideration of adverse events, the model estimated that the 5.5% of individuals experiencing generalized rash also would have experienced fever. The percentage experiencing only fever was arrived at by subtracting 5.5% from 10.2% to get 4.7%. The 4.7% would require admission to a minimal care ward. The second dose is associated with an 8.6% fever rate and a 0.9% rash rate.

Disease-associated costs included both training and medical costs. The cost of training includes the costs of operating the military installation where the training is conducted (e.g., the expense of public safety and other services such as those provided in towns and municipalities) and the actual costs of the training programs (e.g., instructor wages and instructional materials). The military training cost was estimated as the cost of lost productivity as a result of hospitalization (wages paid the soldier during the period of nonproductivity), direct training-associated costs (wages for instructors, training support personnel, and training supplies attributed to training each recruit), and indirect training-associated costs (the utilities and military installation services attributed to each trainee). Training cost data for each site were obtained from TRADOC, and the total cost per day was calculated as $139 (TRADOC, 1997).

The medical cost savings resulting from prevented hospitalized episodes of varicella disease were calculated as 5.4 inpatient bed days and one associated outpatient visit prevented. Direct bed-day costs include physician, nurse, and clerical salaries and supplies. Indirect bed-day costs include ancillary costs (e.g., laboratory services, pharmacy services, radiology services), support costs (e.g., hospital administration, utilities, maintenance, transportation, housekeeping), and a pooled prorated cost for shared facilities. These cost data were obtained from MEDCOM and assessed across all work centers and all Army bases for all admissions associated with ICD-9 code 052.9, for a total cost per bed day of $659 for varicella disease.

Complications associated with varicella disease in adults include varicella pneumonia, secondary bacterial infections, and varicella encephalitis.[14-17] An estimated 26.7 cases of varicella pneumonia and 3.3 cases of varicella encephalitis will occur per 10,000 varicella infections.[18] Hospitalizations associated with varicella complications obtained from MEDCOM and assessed across all work centers and all Army bases for all admissions associated with ICD-9 codes 052.1, 052.7, and 052.8 averaged 7.3 inpatient bed days, for a total cost per bed day of $672, and one associated outpatient visit ($58) (MEDCOM, 1997).[12]

The mortality rates associated with uncomplicated varicella disease in adults have been reported to be as high as 3.1 per 10,000 infections,[19] with a reported 10% to 30% of complications resulting in death.[11,20] An estimated cost of $1 million was associated with any varicella-related death, regardless of age or sex.[21]

Results

Based on an annual incoming male and female population of 100,000 in IET for 8 weeks, in the absence of a varicella prevention program, 36 cases of varicella would develop (Table II) at a cost of $5,028 in medical and training costs per diseased individual, for a total cost of $181,000 (Table III). Alternatively, an IET screening and vaccination strategy would prevent 4 cases of varicella, 0.013 complications, and 0.003 deaths. The IET screening strategy would cost a total of $3,436,000, or approximately $3,255,000 more than the no-intervention strategy. This represents an incremental cost of $813,750 per varicella case prevented over no intervention. A MEPS screening and IET vaccination strategy would prevent an additional 3 cases of varicella, 0.010 complications, and 0.002 deaths. The MEPS screening strategy would cost a total of $2,915,000, or $521,000 less than the IET screening strategy. This represents an incremental savings of $173,667 per case of varicella prevented over the IET strategy. The universal vaccination strategy would prevent an additional 2 cases of varicella, 0.007 complications, and 0.001 deaths. The universal vaccination strategy would cost a total of $18,773,000, or $15,858,000 more than the MEPS screening strategy. This represents an incremental cost of $7,929,000 per case of varicella prevented.

Pairwise comparisons for each strategy are presented in Table IV. MEPS screening would cost $390,571 per case of varicella prevented over the no-prevention strategy. Universal vaccination would cost $2,065,778 per case of varicella prevented over no intervention and $3,067,400 over the IET screening strategy.

Univariate Sensitivity Analyses

Sensitivity analyses independently ranging the values used in the model do not result in significant changes in the cost-effectiveness of the strategies. Even if the costs of vaccine and vaccine administration were both independently varied to no cost ($0), the cost-effectiveness conclusions were not affected because of the cost of side effects and the limited ability of the vaccine to prevent disease during the 8 weeks of IET. Similarly, as the cost of screening was varied toward $0, the conclusions were not affected. If the risk of side effects associated with vaccination approached zero, the cost-effectiveness conclusions were not affected. If the costs of hospitalization for varicella disease or complications were varied to their upper range of $1,101 and $1,152, respectively, the cost-effectiveness conclusions were not affected. If the probability of complications with varicella disease or the chance of death with disease or complications were varied to 0.10 and 0.10, respectively, the cost-effectiveness conclusions were not affected. If the costs associated with death were varied up to $1 billion, the cost-effectiveness conclusions were not affected. Even if the vaccine were 100% effective or the screening assay were 100% sensitive at identifying disease, the cost-saving conclusions were not affected. If the incidence rate of 24.6 per 1,000 susceptible recruits were increased by four times to 98.4 per 1,000 susceptible recruits, the results were not affected. Even if all recruits were susceptible to varicella disease, the cost-effectiveness conclusions were not affected.

Multivariate Sensitivity Analyses

In multivariate sensitivity analyses, the impact of variations in vaccine characteristics and vaccine administration were evaluated. If the risk of adverse events requiring clinical attention approached zero risk and vaccination administration did not include a clinic visit, the cost of the IET screening strategies would decrease by $2,136,000, the MEPS by $1,110,000, and the universal vaccination strategy by $12,554,000, yet the no-prevention strategy still would provide the lowest cost. If the delay in the development of protective antibody approached zero (i.e., vaccine protection provided at time of vaccination), the cost of the IET strategies decreased by $95,000 and the MEPS by $77,000, and they each prevented 23 cases of varicella over no intervention. Similarly, the cost of the universal vaccination strategy decreased by $89,000 and prevented 27 cases of varicella over no intervention. However, the cost of screening and vaccination still exceeded that required for the treatment of cases of varicella and their complications.

Consideration of Herd Immunity

Each year, the Army loses approximately 30% of its active duty soldiers as a result of people retiring, leaving the Army after their tour of enlistment/duty, medical separations, etc. If we were to begin a recruit varicella screening/vaccination strategy, 100% of the Army would not be affected by the strategy instantaneously. After 1 year, the Army could be divided into an unscreened/unvaccinated regular Army cohort (70%) and a screened/vaccinated recruit cohort (30%). Continuing these calculations, after 6 years, only 11.8% of the original unscreened/unvaccinated cohort would be left in the active Army. The rest of the active Army force (88.2%) would be from screened/vaccinated recruit cohorts. Consequently, we can assume that the 88.2% of the screened/vaccinated cohort will be 100% immunized against varicella after 6 years. This leaves only 11.8% who may or may not be immunized against varicella.

TABLE II

REFERENCE CASE: EXPECTED DISEASE OUTCOMES UNDER THE THREE VARICELLA PREVENTION STRATEGIES PER 100,000 NEW RECRUITS DURING A 2-WEEK PERIOD PER RECRUIT ASSUMING A SUSCEPTIBILITY RATE OF 8.8% AND AN INCIDENCE RATE OF 21.6 PER 10,000 PERSON-YEARS

Varicella Prevention Strategies	Projected Cases of Varicella Disease	Incremental Cases of Varicella Prevented	Incremental Complications Prevented	Incremental Deaths Prevented
No vaccination	36	–	–	–
Screen IET, vaccinate IET	32	4	0.013	0.003
Screen MEPS, vaccinate IET	29	3	0.010	0.002
Vaccinate all, IET	27	2	0.007	0.001

TABLE III

REFERENCE CASE: EXPECTED COSTS UNDER THE THREE VARICELLA PREVENTION STRATEGIES PER 100,000 RECRUITS

Varicella Prevention Strategies	Vaccine Costs	Medical/Training Costs	Total Costs[a]	Total Average Cost Savings[b]	Total Incremental Cost Savings[c]
No vaccination	–	$181,000	$ 181,000	$ 0	$ 0
Screen IET, vaccinate IET	$ 3,275,111	$160,889	$ 3,436,000	−$ 3,255,000	−$ 3,255,000
Screen MEPS, vaccinate IET	$ 2,769,194	$145,806	$ 2,915,000	−$ 2,734,000	$ 521,000
Vaccinate all, IET	$18,637,250	$135,750	$18,773,000	−$18,592,000	−$15,858,000

[a]Total costs = vaccine costs + medical/training costs.
[b]Total average cost savings = cost of screen/vaccinate strategy − cost of no-vaccination strategy.
[c]Total incremental cost savings = 1 − (total cost of strategy − total cost of strategy with next lowest cost). Incremental cost savings refer to the cost savings provided by one strategy over the strategy that prevents the next highest level of disease (i.e., step-down comparison). Negative values represent costs over the comparison strategy (i.e., negative cost savings) and positive values represent cost savings over the comparison strategy.

TABLE IV

COST-EFFECTIVENESS COMPARISONS: MATRIX OF STRATEGIES (COST PER CASE PREVENTED)

Varicella Prevention Strategies	Vaccinate All, IET	Screen MEPS, Vaccinate IET	Screen IET, Vaccinate IET	No Vaccination
No vaccination	–	–	–	0
Screen IET, vaccinate IET	–	–	0	$ 813,750
Screen MEPS, vaccinate IET	–	0	−$ 173,667	$ 390,571
Vaccinate all, IET	0	$7,929,000	$3,067,400	$2,065,778

Values in the table represent the cost of the strategy on the *x* axis per case of varicella prevented over the strategy on the *y* axis, represented by the following equation:

$$\frac{\text{cost}_x - \text{cost}_y}{\text{number of varicella cases expected}_x - \text{number of varicella cases expected}_y}.$$

Negative values represent cost savings (i.e., negative costs) per case of varicella prevented, and positive values represent cost per case of varicella prevented.

Dashes represent mirror comparisons. Cases of varicella prevented are presented in Table II, and costs per strategy are presented in Table III.

Previous prevalence studies indicate that 6.9% (adjusted to U.S. general population) of incoming recruits do not have varicella antibodies (6.9% × 11.8% = 0.8%).[4] Consequently, a recruit strategy would result in not only protection of recruits but in herd immunity of 99.2% for the entire Army after 6 years.

Discussion

Varicella represents a cause of preventable morbidity in new recruits each year. However, the implementation costs of screening and vaccination far exceed the costs of treatment of varicella and its complications. A treatment strategy in which no screening or vaccination is offered provides the lowest cost of all strategies presented. This conclusion is not significantly altered by variation in any one of the variables in the model used for this analysis.

Other cost-effectiveness analyses conducted in a variety of settings have concluded that vaccination for varicella is cost-effective.[3,22,23] These studies were conducted under a multiple-year surveillance period and used varied exposure rates. Because of the relevant and costly disruptions to training by varicella, we were interested in the prevention capabilities of vaccination within the initial basic training period of 8 weeks. As a result of delayed production of protective antibodies, at an average of 4 weeks the potential of vaccine to prevent disease during this period is limited. Our study modeled a varicella hospitalization rate of 21.6 per 10,000 person-years, or 36 cases per 100,000 new recruits. Alternatively, Nettleman and Schmid[23] analyzed the worth of varicella vaccination in health care workers and used 1 case per 630 employees, equating to 159 cases per 100,000 employees. Lieu et al.[22] analyzed the value of vaccination in children and used a rate of 9,156 per 100,000 individuals. Both incidence levels far exceed the level seen in our population.

Additionally, receipt of medical care for vaccine-related adverse events in the training setting is conservative or absent in other analyses. In the military, individuals with fever greater than 100°F are hospitalized due to the long duration of unattended hours if a new recruit becomes ill and to properly monitor and prevent the development of complications. Additionally, close-quarter living conditions necessitate hospitalization of recruits with varicella-like rash reactions to the vaccine to prevent any contact with susceptible recruits and to rule out natural infection. In the civilian setting, it is unlikely that these conditions would require inpatient care; consequently, adverse events with vaccination are not usually modeled. An earlier study conducted in U.S. Air Force Academy cadets determined screening and vaccination of new cadets to be cost-effective for prevention of hospitalizations.[3] This study modeled a vaccination cost of $74.92 for two doses of vaccine and administration, $64.63 less than our modeled total vaccine cost and assumed clinic visit ($58) for the second dose in the MEPS screening and vaccinate-all strategies. The cost in that study was $121.46 less than our modeled total vaccine cost and two clinic visits for the IET screening strategy. Additionally, the Air Force study modeled more hospital days for varicella disease, used a higher incidence rate, assessed vaccine prevention potential over a 4-year period, and did not consider adverse events associated with vaccination. Consequently, that model is not necessarily comparable with our model.

We did not model the benefits provided by retaining readiness and scheduling of training sessions. Recruits are recycled if they incur too many missed training days. In the event that a recruit misses too many training days, he or she must restart training. If this occurred, it would disrupt recruiting procedures and the schedules for specialty training that follow basic training, increasing the military costs associated with varicella disease and increasing the cost-effectiveness of vaccination. Additionally, our model operated under a 1-year analytic horizon for new recruits and only considered vaccine protection during the period of IET. Consequently, there may be additional benefits associated with the extended effects of a screening and/or vaccination strategy than those modeled here. As discussed, a screening and vaccination strategy not only provides protection of recruits but would result in herd immunity of 99.2% for the entire Army after 6 years. However, there are limitations in assessing and quantifying the total impact of a screening and vaccination strategy on an Army-wide herd immunity benefit. First, because the susceptible cohort incoming each year in the absence of a screening and vaccination strategy accounts for a small proportion of the total Army, we will experience a decline in the number of susceptible soldiers in the Army as a whole. Consequently, the benefit associated with the prevention strategy will not remain static. Second, we have noticed a decreasing trend in the Army's and Navy's varicella incidence rates even in the absence of a screening and vaccination strategy. The civilian licensure of varicella vaccine and the increasing practice of varicella vaccine administration to children should also result in decreasing incidence rates. Consequently, the magnitude of the total Army herd immunity benefit could be substantially decreased as a result of the continuing downward trend in recruit incidence rates and the increasing impact of the use of the vaccine in children. Approximately 91% of incoming recruits have protective antibodies against varicella.[4] Herd immunity may naturally increase even in the absence of a recruit screening/vaccination strategy, thus decreasing the relative benefit of this effect in the consideration of implementation of a screening and vaccination strategy.

In 1990, Gray et al. analyzed surveillance data for the U.S. Navy and Army and found that rates increased more than 4-fold from 1980 to 1988.[6] This trend may have reversed in subsequent years, as reported by Herrin and Gray.[7] These researchers identified a decreased hospitalization rate for varicella, from 258/100,000 persons during the peak of 1987 to 74/100,000 persons in 1994.[7] Additionally, the rate of 8.8% in incoming recruits who lack protective antibody may be declining, and the rate of individuals vaccinated for varicella before entry into the military may be increasing. Rates also may be decreasing as a result of current American Committee on Immunization Practice recommendations for pediatric use of varicella vaccine. Consequently, the incidence rate used in the analysis may overestimate the varicella rates to be expected in the future, decreasing the absolute value of vaccination in new recruits.

There exist several potential strategies that were not modeled and that require discussion. Questionnaires that obtain information on past disease history to provide prescreening information or to verify a negative screening test have also been suggested.[1,3,23] Studies that have reviewed the value of this strategy are conflicting. A recent study conducted at Fort Gordon during advanced individual training (training for recruits after IET) by Jerant et al. found that use of a questionnaire to determine history of clinical varicella disease would be useful for screening.[1] The positive predictive value of the questionnaire was 98.5%, whereas the negative predictive value was 23%. However, at the Naval Hospital at Great Lakes, 43% of naval recruits with seropositive evidence for varicella infection reported having had disease and 13% of seropositive individuals reported not having had disease (Armed Forces Epidemiology Board, August 1997). Therefore, a questionnaire is not used at Great Lakes to screen for varicella history. All recruits are screened for varicella by antibody test and are appropriately vaccinated. In our study, administration of questionnaires to increase the sensitivity and specificity of screening would not have altered the conclusion because of the magnitude of difference between the strategies. Additionally, specific groups have been identified as high risk for adult onset of varicella disease, such as African Americans, Hispanics, and individuals from the Virgin Islands, Puerto Rico, and Hawaii.[5] Institution of targeted screening or vaccination could be viewed as inequitable or discriminatory, and thus it does not represent a socially viable prevention alternative.

We evaluated the value of screening U.S. Army recruits at the MEPS to provide earlier vaccinations and thus earlier protection. Although this strategy performed better than the IET strategy, saving approximately $174,000 per case of varicella prevented, screening infrastructures at MEPS are currently not available and their feasibility of implementation is unknown. The main function of MEPS is to determine the entrance qualifications of military applicants, not to provide medical services.

Screening and vaccinating new recruits to provide protection against varicella is not cost-effective under the conditions in our reference model. The delay in vaccine-provided antibodies negates the vaccine's prevention potential during the initial 8-week training period, when illness from varicella would have the strongest negative economic effect. However, even in the absence of this delay, the cost of vaccination still renders a no-intervention strategy the lowest-cost strategy. If disease after IET were to be considered, in which case the potential of eradication of varicella from the Army in 6 years exists, this conclusion may be altered. However, continued low incidence rates are possible, and the value of preventing varicella disease substantially decreases after basic training. Increasing rates of complications or inclusion of other potential complications (e.g., zoster) may alter this conclusion from a clinical perspective. However, this analysis indicates that vaccination of new recruits against varicella is not a cost-effective use of scarce military health care resources.

Acknowledgments

We acknowledge the assistance and support provided by COL Jerome Karwacki, COL Robert DeFraites, and LCDR Sharon Ludwig.

References

1. Jerant AF, DeGaetano JS, Epperly TD, Hannapel AC, Miller DR, Lloyd AJ: Varicella susceptibility and vaccination strategies in young adults. J Am Board Fam Pract 1998; 11: 296–306.
2. Centers for Disease Control: Epidemiology and Prevention of Vaccine Preventable Disease, Ed 3. 99185-93. Washington, DC, Department of Health and Human Services, 1996.
3. Burnham BR, Wells TS, Riddle JR: A cost-benefit analysis of a routine varicella vaccination program for United States Air Force Academy cadets. Milit Med 1998; 9: 631–4.
4. Kelley PW, Petruccelli BP, Sehr-Green P, Erickson RL: The susceptibility of young adult Americans to vaccine-preventable infections: a national serosurvey of US Army recruits. JAMA 1991; 266: 2724–9.
5. U.S. Army Center for Health Promotion and Preventive Medicine: Varicella among active duty soldiers: January 1990–July 1997. Medical Surveillance Monthly Report 1997; October: 2–9.
6. Gray GC, Palinkas LA, Kelley PW: Increasing incidence of varicella hospitalizations in United States Army and Navy personnel: are today's teenagers more susceptible? Should recruits be vaccinated? Pediatrics 1990; 86: 867–73.
7. Herrin VE, Gray GC: Decreasing rates of hospitalizations for varicella among young adults. J Infect Dis 1996; 174: 835–8.
8. Demmler GJ, Steinberg SP, Blum G, Gershon AA: Rapid enzyme-linked immunosorbent assay for detecting antibody to varicella-zoster virus. J Infect Dis 1988; 157: 211–2.
9. Gordon JE: Chickenpox: an epidemiological review. Am J Med Sci 1962; 244: 362.
10. Rotter R, Collins JD: Fatal disseminated varicella in adults: report of a case and review of the literature. Wis Med J 1961; 60: 325.
11. Tribwasser JH, Harris RE, Bryant RE, Rhoades ER: Varicella pneumonia in adults: report of seven cases and a review of the literature. Medicine 1967; 46: 409–23.
12. Howell MR, Nang RN, Gaydos CA, Gaydos JC: Prevention of adenoviral acute respiratory disease in Army recruits: cost-effectiveness of a military vaccination policy. Am J Prev Med 1998; 14: 168–75.
13. Lee T, Nang RN: The epidemiology of varicella hospitalizations in the U.S. Army. Milit Med (in press).
14. Choo PW, Donahue JG, Manson JE, Platt R: The epidemiology of varicella and its complications. J Infect Dis 1995; 172: 706–12.
15. Davidson RN, Lynn W, Savage P, Wansbrough-Jones MH: Chickenpox pneumonia: experience with antiviral treatment. Thorax 1988; 43: 627–30.
16. Joseph SG, Oser B: Complications of varicella pneumonia in adults. J Am Osteopath Assoc 1993; 93: 941–7.
17. Centers for Disease Control: Prevention of varicella: recommendations of the Advisory Committee on Immunization Practices. MMWR 1996; 45: RR-11.
18. Guess HA, Broughton DD, Melton LJ, Kurland LT: Population-based studies of varicella complications. Pediatrics 1986; 78(suppl): 723–7.
19. Preblud SR: Varicella: complications and costs. Pediatrics 1986; 78(suppl): 738–5.
20. Waring JJ, Neuberger K, Greever ER: Severe forms of chickenpox in adults. Arch Intern Med 1942; 69: 384–408.
21. Centers for Disease Control and Prevention: A Practical Guide to Prevention Effectiveness: Decision and Economic Analyses. Atlanta, GA, US Public Health Service, 1992.
22. Lieu TA, Cochi SL, Black SB, Halloran E, Shinefield HR, Holmes SJ, Wharton M, Washington AE: Cost-effectiveness of a routine varicella vaccination program for US children. JAMA 1994; 271: 375–81.
23. Nettleman MD, Schmid M: Controlling varicella in the healthcare setting: the cost-effectiveness of using varicella vaccine in health care workers. Infect Control Hosp Epidemiol 1997; 18: 504–8.