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EDITORIAL

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geons, the American Dental Association, and numerous other professional organizations opposed the CDC recommendations.[7,8] Further, the National Commission on AIDS came out strongly against mandatory screening proposals, calling them counterproductive and stating that they may "ultimately cause greater patient morbidity and mortality than they prevent."[9]

Professional opposition has rested on the conviction that the risk of transmission of HIV from practitioner to patient is very small, even during invasive procedures. Our analysis examines a related claim against HIV testing, that it constitutes a poor use of limited healthcare resources. This argument maintains that funds would be better spent on health programs that are more effective than screening healthcare workers for HIV.

Our first objective is to estimate the cost-effectiveness of four HIV screening strategies for surgeons and dentists to allow comparisons with other lifesaving interventions. A second objective is to determine the relative (incremental) cost-effectiveness of the types of screening programs that have been proposed.

SCREENING ALTERNATIVES

We estimate the cost-effectiveness of mandatory, voluntary, one-time, and annual HIV screening programs for two classes of healthcare workers: surgeons and dentists. We focus on these occupations because both frequently perform invasive procedures, offering the most credible risk of HIV transmission, and because the cost-effectiveness of programs targeted to surgeons and dentists should provide optimistic estimates of the cost-effectiveness of healthcare worker screening in general.[10]

We consider the cost-effectiveness of programs for surgeons and dentists separately, examining four possible screening strategies for each group: one-time voluntary screening (1TM-VOL), one-time mandatory screening (1TM-MAN), annual voluntary screening (AN-VOL), and annual mandatory screening (AN-MAN). Mandatory programs would require testing, with penalties for practitioners failing to comply. These might be required by law or by hospitals and insurance companies seeking to prevent lawsuits. Voluntary programs would be promoted by professional societies, federal agencies, and healthcare providers, but no incentives or penalties would be associated with the programs.

We assume standard HIV screening procedures in our model.[11] Every tested individual first is administered a single enzyme-linked immunosorbent assay test (ELISA). If the ELISA is positive, it is repeated twice; if either of the second two tests is positive, the tested individual is considered ELISA positive. ELISA-positive individuals are confirmed with a single Western Blot test (WB). An individual is considered HIV positive only if both ELISA and WB are positive.

METHODS

Cost-Effectiveness of Programs

To determine cost-effectiveness, we separately estimated the total costs and number of infections occurring under each of the screening scenarios, using Microsoft Excel spreadsheets (Microsoft Excel Version 4.0. Copyright 1985-1992). We then compared the programs with each other and with a "no screening" option. This cost-effectiveness analysis was conducted from the societal perspective.

We projected the costs and number of surgeon-to-patient or dentist-to-patient HIV infections occurring under each screening scenario for a 15-year period beginning on January 1, 1994. The 15-year period includes 1 year for implementation and a 14-year follow-up. We assumed that any of these programs, if implemented, would be re-evaluated after this time.

For the one-time programs (voluntary and mandatory), screening is conducted only during the first year. Treatment costs for those identified and morbidity savings from transmissions prevented are projected for the remaining 14 years, but no new program costs are incurred. In the two annual screening programs, testing is conducted during each of the 15 years. There are no screening costs in the "no screening" scenario, which assumes that surgeons and dentists never are tested. However, under all scenarios, those HIV-infected doctors developing acquired immunodeficiency syndrome (AIDS) are removed from practice to account for departure from practice due to infection.

Progression of HIV

We based our average length of time until the development of AIDS from HIV infection on the following staging model of the progression of HIV infection: 1) HIV-positive without AIDS (T-cell count $\geq 0.50 \times 10^9/L$), 2) HIV-positive without AIDS (T-cell count ≥ 0.20 and $< 0.50 \times 10^9/L$), 3) HIV-positive without AIDS (T-cell count $< 0.20 \times 10^9/L$) and 4) AIDS. On average, a person remains in the first stage for 5.6 years, the second stage for 4.7 years, the third stage for 1 year, and the fourth stage for 2.1 years.[12,13] Therefore, persons infected with HIV develop AIDS in 11.3 years on average (the total average time in stages 1 through 3). Therefore, we allow doctors who become infected during the 15-year period to remain in practice in the "no screening" scenario and screening scenarios (when they escape detection) for 11.3 years. Doctors infected and practicing at the beginning of the screening programs are assumed to have been infected at a constant rate over the previous 11.3 years and are allowed to remain in the model until they reach 11.3 years or are detected by screening. Those withdrawn from practice cannot transmit HIV infection during subsequent years.

Costs of Screening

For program costs under each screening scenario, we include direct program costs, additional treatment costs for HIV-positive surgeons and dentists who are identified earlier than they otherwise would have been, and avoided treatment costs for patients not infected with HIV because of the screening programs.

The direct program costs include the cost of the ELISA and WB tests and the cost of counseling. We estimate the cost of an ELISA at $3.44 and a WB at $34.67.[14] These are average costs to testing sites (from a survey of federally funded testing sites) and include the cost of the test kits, personnel time, fringe benefits, and overhead. We estimate the costs of pre- and posttest counseling at $39.18 for all tested individuals, with an additional $31.43 in counseling costs at the time of testing for HIV-positive individuals.[14] The counseling costs are average costs to a testing site and include the cost of counselors, supervisors, and clerical time as well as fringe benefits and overhead.

Additional costs for treatment of surgeons and dentists testing HIV positive are included in the model. We presume doctors who have progressed to stage 3 prior to the screening program have identified their infections independent of the screening programs and that their HIV/AIDS treatment costs are not a result of the program. Therefore, we only include the costs associated with stages 1 and 2 in the model. These costs include hospitalization, outpatient medical visits, home healthcare involving medical services, and drugs, and are estimated as $3,387 per year (stage 1) and $5,160 per year (stage 2) on the basis of charges by Hellinger.[12]

A final component of cost is the savings in avoided treatment for HIV infections that do not occur due to the screening program. To calculate this offset, over time we follow patients who would have contracted the virus from their surgeon or dentist but did not as a result of the program. We assume that these individuals would have identified their HIV infection and begun treatment in stage 3 of the disease. Stage 3 costs $11,880 per year, and stage 4 costs $33,168 per year on average for hospitalization, long-term care services, outpatient medical visits, home healthcare involving medical services, and drugs.[12]

Our HIV/AIDS treatment costs for each of the four stages of HIV infection were calculated using the pre-1993 CDC AIDS definition. Under the new definition, some costs likely will shift from earlier to later stages, but total treatment costs and our cost-effectiveness results will remain the same. Our model predicting transitions through the four stages also is based on the pre-1993 CDC AIDS definition. Because we consistently used the pre-1993 AIDS definition, our total program costs will not be affected.

Costs not in the model include net productivity losses for surgeons and dentists found to be HIV positive (net losses would depend on policies regarding employment of HIV-positive individuals, but would reflect changes in or loss of employment as well as productivity gains as a result of early treatment for practitioners identified), future costs of morbidity for patients who escape infection as a result of screening programs (costs of non-HIV causes of illness and death), costs of any screening-induced injuries, and potential additional costs of a screening program, such as new equipment, personnel, or administration. We expect that each of these excluded costs would make screening less cost-effective.

NUMBER OF HIV INFECTIONS PREVENTED

Our model defines program effectiveness as the number of patient infections prevented during the 15-year period. This is an intermediate outcome measure, a disadvantage of which is that it does not fully reflect the ultimate goal of saving years of life. Measuring costs per transmission prevented also makes the cost-effectiveness figures less comparable to the results of other analyses, which generally measure cost per life saved or per life-year saved.[15] However, the number of transmissions prevented reflects the most immediate purpose of the programs, and it does not require assumptions about length of life, which would add to uncertainty in the analysis.

The number of infections prevented is calculated from projections of the number of practitioner-to-patient infections occurring without a screening program and under each screening scenario. The number of patient infections occurring incorporates 1) the number of HIV-positive surgeons or dentists at the beginning of the program, 2) the number of HIV-positive practitioners screened, 3) incident infections during the 15-year period, 4) the ability of the screening programs to reduce risky contacts between HIV-positive practitioners and patients during invasive procedures, and 5) rates of HIV transmission from surgeon or dentist to patient. These components are described below.

HIV transmissions not included in our model include those that would occur outside of the doctor-patient relationship. For example, we do not consider, as a result of the screening programs, increases and

TABLE 1
NUMBER OF INFECTED SURGEONS AND DENTISTS AT BEGINNING OF SCREENING PROGRAM

	No. Doctors Reported with AIDS on September 30, 1991*	Population Reported with AIDS on September 30, 1991†	Proportion of Population with AIDS‡	No. HIV Positive§	Estimated No. HIV-Infected Doctors¶
Surgeons	53	151,941	0.000349	1,000,000	349
Dentists	209	151,941	0.001376	1,000,000	1,376

* Number of surgeons and dentists reported to the CDC with AIDS as of September 30, 1991. Source: CDC data: personal communication, January 1992.
† Number of people reported with AIDS and occupational data to the CDC as of September 30, 1991. Source: CDC data: personal communication, January 1992.
‡ Proportion of persons with AIDS on September 30, 1991, who are surgeons or dentists (column 1 divided by column 2).
§ Number of HIV-positive persons in the United States. Source: *MMWR* February 23, 1990).
¶ Estimated number of HIV infected surgeons and dentists (without AIDS) on January 1, 1994 (column 3 times column 4).

decreases in the number of transmissions from infected doctors to their sexual and intravenous drug-using partners. Nor do we consider transmissions and prevented transmissions from patients to their sexual and intravenous drug-using partners.

HIV-Infected Surgeons and Dentists at Beginning of Programs

Table 1 presents our estimates of the number of surgeons and dentists infected with HIV at the initiation of the screening programs on January 1, 1994. This group represents the initial number of HIV-positive practitioners who could be detected by screening programs. The numbers are calculated by multiplying the national estimate for the number of HIV-infected people by the proportion of people with AIDS (reported to the CDC) who are surgeons and dentists. This assumes that the proportion of surgeons and dentists with AIDS is the same as the proportion with HIV infection. Our figure for infected dentists may be overestimated because the numbers used to calculate this figure included a number of dental workers other than dentists who cannot be differentiated from dentists as a result of the official AIDS reporting process.[16] To the extent that this occurred, our estimate of the number of infected dentists is an overestimate. On the other hand, the CDC figures for the number of infected surgeons and dentists also may have been underestimated due to underreporting of AIDS to the CDC, biasing our estimates downward.

Practitioner Screening

Table 2 presents our estimates of the number of practicing surgeons and dentists eligible for screening during the years 1994 to 2008. The number of surgeons is based on estimates of the number of active surgeons in the year 1986 and projections for the year 2000.[17] Estimates for the years between 1986 and 2000 are interpolated linearly, and years beyond 2000 are extrapolated linearly from the 1986 and 2000 estimates. Dentist projections are taken from American Dental Association estimates for the years 1994 through 2000. Figures for the years 2001 through 2004 are interpolated linearly from estimates for the years 2000 and 2005, and years 2006 through 2008 are extrapolated linearly from these estimates.[18]

The number of new surgeons is assumed constant each year of our model and is estimated as the number of graduate first-year residents on duty September 1, 1990.[19] Estimates of the number of new dentists each year are taken directly from estimates for 1994 through 2000, and projections for the years 2001 through 2004 are interpolated linearly from estimates for the years 2000 and 2005.[18] Years 2006 through 2008 are extrapolated from the estimates for years 2000 and 2005.

Under mandatory screening scenarios, we assume all surgeons and dentists were tested, regardless of their HIV status. Under voluntary screening scenarios, we assume 90% of HIV-positive and 50% of HIV-negative surgeons and dentists are tested. This results in slightly more than 50% of all surgeons and dentists being tested. Our estimate of the total number screened is based on the results of a voluntary screening of orthopedic surgeons at an annual conference, during which 48% submitted to testing.[20,21] An unrelated survey of surgeons in Washington, DC, found that 44% had been screened for HIV in the previous year (Hirsch RP, Associate Chairman for Research, Department of Health Care Sciences, George Washington University; personal communication; April 1992). We assume that practitioners who believe they have been exposed to HIV either in personal or clinical contacts are more likely to pursue testing.[22]

TABLE 2
Projected Number of Surgeons and Dentists, 1994-2008

Year	Total No. Surgeons*	No. Surgeons Newly Graduated	Total No. Dentists*	No. Dentists Newly Graduated
1994	152,217	2,408	141,859	3,600
1995	154,439	2,408	142,105	3,589
1996	156,661	2,408	142,249	3,570
1997	158,884	2,408	142,381	3,566
1998	161,106	2,408	142,501	3,555
1999	163,328	2,408	142,628	3,539
2000	165,550	2,408	142,793	3,520
2001	166,411	2,408	142,714	3,520
2002	167,272	2,408	142,635	3,520
2003	168,133	2,408	142,556	3,520
2004	168,994	2,408	142,477	3,520
2005	169,855	2,408	142,398	3,520
2006	170,716	2,408	142,041	3,520
2007	171,577	2,408	141,683	3,520
2008	172,438	2,408	141,325	3,520

* New graduates included in total.

HIV-Infected Surgeons and Dentists After Initial Screening

In one-time screening programs, practitioners who are HIV infected as of January 1, 1994, represent the universe of detectable cases. In annual screening programs, additional infections can be detected each year. These will include 1) cases missed (false-negative) during previous years, 2) newly infected practitioners, and 3) entering new graduates who are HIV infected.

The number of false-negative test results is determined by the test performance of the ELISA/WB sequence. Our model assumes ELISA sensitivity of 98% and specificity of 99.5%, and WB sensitivity of 92% and specificity of 95% among samples previously testing ELISA positive.[23,24] We assume that all infected practitioners are detectable by tests from the time they become infective to patients, ie, we do not account for a "window" period before the appearance of HIV antibody. When an HIV-positive individual screens negative (ELISA- or ELISA+/WB-), he or she remains in a full practicing clinical position where he or she potentially could transmit the virus. We assume that the probability of transmission by a surgeon or dentist who has a false-negative test is the same as that of an unscreened HIV-positive surgeon or dentist.

We assume the incidence of HIV infection among surgeons and dentists who are uninfected at the beginning of the program to be 0.00003% per year for the remainder of the program. This estimate is derived from Red Cross data on repeat blood donors.[25] Finally, we assume that the prevalence of HIV infection among all newly graduated surgeons and dentists entering their occupation is the same as the initial prevalence of HIV infection among surgeons and dentists at the beginning of the screening programs.

HIV-Positive Practitioner Risk Reduction

We assume that mandatory screening programs require all surgeons and dentists testing HIV positive to retire from practice or to eliminate all potentially risky patient contact. Therefore, risk of transmission after a positive test is assumed to be zero in the mandatory screening scenarios. Under a voluntary screening program, we assume that most of those with a positive result will reduce their risk of transmission in accordance with professional ethics and the recommendations of their professional organizations.[26,27] We assume 90% would eliminate all risk of transmission to patients, and the remaining 10% would continue to practice as before.

Surgeon- and Dentist-to-Patient Transmission Rates

The CDC estimates that the transmission rate of HIV from infected surgeon to patient ranges from 24 to 240 transmissions per 10 million procedures. The range for dentists is 36 to 360 transmissions per 100 million procedures.[28] For our baseline analysis, we have developed an average transmission rate scenario. This average transmission rate scenario uses the average of the per-procedure transmission rate

TABLE 3A
COST-EFFECTIVENESS OF HIV SCREENING PROGRAMS FOR SURGEONS*

	Total Cost of Program	Transmissions Occurring Under Program	Transmissions Prevented	Incremental Cost/ Incremental Effect†
Assuming an Average Transmission Rate Scenario				
No Screen	$ 0	12.13	0.00	$ 0
1TM-Vol	6,956,998	4.39	7.74	899,336
1TM-Man	10,651,388	2.65	9.48	2,120,981
AN-Vol	46,076,416	0.84	11.29	19,583,829
AN-Man	82,897,890	0.26	11.87	63,323,152
Assuming a Maximum Transmission Rate Scenario				
No Screen	$ 0	75.66	0.00	$ 0
1TM-Vol	8,508,057	27.41	48.25	176,311
1TM-Man	12,596,656	16.54	59.12	376,286
AN-Vol	48,187,891	5.25	70.41	3,154,136
AN-Man	85,170,256	1.63	74.03	10,195,442
Assuming a Minimum Transmission Rate Scenario				
No Screen	$ 0	2.20	0.00	$ 0
1TM-Vol	6,714,567	0.80	1.40	4,787,928
1TM-Man	10,347,342	0.48	1.72	11,504,349
AN-Vol	45,746,392	0.15	2.05	107,946,467
AN-Man	82,542,718	0.05	2.15	349,056,111

* Total costs, transmissions occurring under program and transmission prevented discounted at 5% to January 1, 1994.
† Incremental cost/effectiveness figures cannot be calculated exactly from table figures due to rounding.

estimates for each profession, 132 transmissions per 10 million procedures for surgeons and 198 transmissions per 100 million procedures for dentists. However, we also assume that one surgeon and one dentist each year have a much higher transmission rate of 588 transmissions per 100,000 procedures. This additional assumption accounts for one practitioner each year who infects patients at a rate consistent with the dental practice where HIV was transmitted.[2] Five of approximately 850 of this dentist's patients are believed to have contracted HIV from him in a clinical setting. To derive our transmission rate, we assume that each patient had only one procedure performed.[28]

Our transmission rates are estimated in units of transmissions per procedure. Therefore, it is necessary to know the number of procedures performed per year to calculate the number of transmissions. We estimate that surgeons perform 500 procedures and dentists perform 3,000 procedures per year.[28] We also assume that healthcare workers infected between screens in the yearly screening scenarios are infected and able to transmit the virus for half of the year. This estimate assumes that practitioners are infected at a constant rate throughout the year.

DISCOUNTING COSTS AND TRANSMISSIONS PREVENTED

All program costs and effects (transmissions prevented) incurred in future years are discounted at 5% per annum to January 1, 1994. This is standard economic practice to account for the fact that future program costs and effects, even controlling for inflation, are not equal in value to current costs and effects.[29] This is because money spent on a screening program today could be invested alternatively elsewhere. For example, $100 invested at 5% interest would yield $105 in 1 year. Discounting corrects for this phenomenon and allows us to sum all discounted costs and effects incurred in future years to derive a single cost-effectiveness ratio.

SENSITIVITY ANALYSIS

In order to determine the sensitivity of the model to its assumptions, critical cost and probability estimates are varied over a range of plausible values to determine their impact on the final cost-effectiveness ratios. Parameters varied include the probability of HIV transmission to patients in clinical settings, number of infected surgeons and dentists at initiation of

TABLE 3B
COST-EFFECTIVENESS OF HIV SCREENING PROGRAMS FOR DENTISTS*

	Total Cost of Program	Transmissions Occurring Under Program	Transmissions Prevented	Incremental Cost/ Incremental Effect†
Assuming an Average Transmission Rate Scenario				
No Screen	$ 0	267.21	0.00	$ 0
1TM-Vol	23,448,553	99.21	168.00	139,571
1TM-Man	29,725,039	57.98	209.23	152,264
AN-Vol	71,965,060	19.33	247.88	1,092,856
AN-Man	101,264,026	5.98	261.23	2,194,081
Assuming a Maximum Transmission Rate Scenario				
No Screen	$ 0	1,666.55	0.00	$ 0
1TM-Vol	59.887,104	618.75	1,047.80	57,155
1TM-Man	75,490,340	361.66	1,304.89	60,693
AN-Vol	121,287,690	120.61	1,545.94	189,986
AN-Man	154,352,722	37.32	1,629.23	397,019
Assuming a Minimum Transmission Rate Scenario				
No Screen	$ 0	48.43	0.00	$ 0
1TM-Vol	17,751,486	17.98	30.45	582,955
1TM-Man	22,569,760	10.51	37.92	644,901
AN-Vol	64,253,602	3.50	44.93	5,950,154
AN-Man	92,963,754	1.08	47.35	11,861,991

* Total costs, transmissions occurring under program and transmission prevented discounted at 5% to January 1, 1994.
† Incremental cost/effectiveness figures cannot be calculated exactly from table figures due to rounding.

the program, the yearly incidence of HIV infection, the percentage of infected and uninfected surgeons and dentists who are tested, the degree to which an HIV-positive identified surgeon or dentist would reduce risk, the costs of testing and counseling, the costs of HIV/AIDS treatment, and the number of procedures performed per year. Each of these has an impact on the results and is described below.

RESULTS

Screening Cost-Effectiveness

Tables 3A and 3B present the main results of our cost-effectiveness analysis of screening programs. Included are total costs, the number of transmissions still occurring under each program, the number of prevented transmissions for each program, and the resulting incremental cost-effectiveness ratios. The baseline results are presented for surgeons and dentists separately, using the average transmission rate scenario described above. These are followed by results assuming maximum and minimum transmission rate scenarios.

We found total discounted costs of screening programs of surgeons (Table 3A) in our baseline analysis range from $7.0 million for a one-time voluntary screening program to $82.9 million for an annual mandatory screening program. For dentists (Table 3B), discounted program costs range from $23.4 million for a one-time voluntary screening program to $101.3 million for an annual mandatory screening program. We project about 12 cases of HIV transmission would occur without a surgeon screening program in the years 1994 to 2008 (Table 3A). A one-time voluntary screening program would prevent 60% (about eight) of these cases, while a 15-year mandatory program would avoid virtually all (Table 3A). For dentists, we project 267.21 HIV transmissions would occur without a screening program during the years 1994 to 2008 (Table 3B). Of these, a one-time voluntary program would prevent about 60% (168 cases), while a 15-year mandatory program would prevent almost all (Table 3B).

For both surgeons and dentists, one-time voluntary screening programs are most cost-effective, costing about $899,338 (Table 3A) and $139,571 (Table 3B) per transmission prevented respectively. These programs are more expensive than many other interventions to prevent HIV transmissions, but are an

TABLE 4A

SENSITIVITY ANALYSIS OF THE COST-EFFECTIVENESS OF SURGEON HIV SCREENING PROGRAMS (BASIS FOR COMPARISON: $899,336 PER PREVENTED TRANSMISSION)*

Variable Altered	Base Value	Lower Bound/ Upper Bound†	Resulting Most Cost-Effective Program Results: Lower Bound/Upper Bound	
No. Infected Surgeons	349	174	1TM-Vol	$1,154,530
		698	1TM-Vol	742,644
HIV Incidence	0.00003	0.000003	1TM-Vol	1,032,572
		0.0003	1TM-Vol	393,740
% Infected Surgeons Tested	90	50	1TM-Man	1,123,857
		100	1TM-Vol	861,238
% Uninfected Surgeons Tested	50	25	1TM-Vol	689,988
		100	1TM-Man	1,123,857
% Of HIV-Positive Surgeons Who Do Not Reduce Risk	10	0	1TM-Vol	816,823
		50	1TM-Man	1,123,857
Cost per ELISA	$3.44	0	1TM-Vol	864,906
		6.88	1TM-Vol	933,766
Cost per WB	$34.67	0	1TM-Vol	898,243
		69.34	1TM-Vol	900,429
Cost of Counseling	$39.18	0	1TM-Man	493,993
		78.36	1TM-Vol	1,286,181
Cost of HIV/AIDS Treatment	$119,274‡	59,637	1TM-Vol	660,852
		238,548	1TM-Vol	1,376,305
Procedures/Year	500	250	1TM-Vol	1,760,394
		1,000	1TM-Vol	468,807

* Our baseline value: 1TM-Vol $899,336 per prevented transmission. This assumes an average transmission rate scenario.
† As each parameter is varied all other parameters are held constant at their base value.
‡ These are total HIV/AIDS treatment costs. Costs are entered into the model according to stage (see description in text). For this sensitivity analysis costs for each stage were halved and doubled simultaneously, in effect halving and doubling total HIV/AIDS treatment costs.

order of magnitude less expensive than yearly mandatory programs that cost $63.3 million (Table 3A) for every surgical transmission prevented and $2.2 million (Table 3B) for every dental transmission prevented.

Sensitivity of Results

Our initial sensitivity analysis addresses the assumptions we make regarding per-procedure rates of transmission from infected practitioner to patient. We examine two alternatives, minimum and maximum transmission rate scenarios. For the minimum transmission rate scenario, we use the lower bound of the transmission range estimated by the CDC as described earlier. For the maximum transmission rate scenario, we use the upper range values and, in addition, we assume that 1% of practitioners (rather than a single surgeon and dentist) are more infective, at a rate of 588 transmissions per 100,000 procedures. These results are presented in Tables 3A and 3B.

For surgeons, the cost per prevented transmission of a one-time voluntary screening program is $176,311 in the maximum transmission rate scenario and $4.8 million in the minimum transmission rate scenario (Table 3A). Varying the transmission rate scenarios produces a similarly dramatic change in results for dentists. For dentists, the cost per prevented transmission of a one-time voluntary screening program is $57,155 in the maximum transmission rate scenario and $582,955 in the minimum transmission rate scenario (Table 3B).

In Tables 4A and 4B, we examine how other model assumptions affect our results. The last column of this table presents the most cost-effective program after the assumption has been varied. For example, our model assumes that there are 349 infected surgeons as of January 1, 1994. If we halve this estimate, cost-effectiveness remains lowest for the one-time voluntary program but increases from our baseline cost-effectiveness ratio of $899,336 to $1,154,530. If the estimate is doubled to 698 surgeons, the ratio decreases to $742,644 per prevented transmission.

None of the assumptions in Tables 4A and 4B radically change our main findings. That is, no program's cost-effectiveness ratio is particularly sensitive to modification of the assumptions. For surgeons, the

TABLE 4B

SENSITIVITY ANALYSIS OF THE COST-EFFECTIVENESS OF DENTIST HIV SCREENING PROGRAMS (BASIS FOR COMPARISON: $139,571 PER PREVENTED TRANSMISSION)*

Variable Altered	Base Value	Lower Bound/ Upper Bound†	Resulting Most Cost-Effective Program Results: Lower Bound/Upper Bound
No. Infected Dentists	1,376	688	1TM-Vol $152,329
		2,752	1TM-Man 129,389
HIV Incidence	0.00003	0.000003	1TM-Vol 144,014
		.0003	1TM-Vol 106,847
% Infected Dentists Tested	90	50	1TM-Man 142,578
		100	1TM-Vol 137,533
% Uninfected Dentists Tested	50	25	1TM-Vol 130,654
		100	1TM-Man 142,072
% of HIV-Positive Dentists Who Do Not Reduce Risk	10	0	1TM-Vol 129,537
		50	1TM-Man 142,072
Cost per ELISA	$3.44	0	1TM-Vol 138,059
		6.88	1TM-Vol 141,083
Cost per WB	$34.67	0	1TM-Vol 139,372
		69.34	1TM-Vol 139,769
Cost of Counseling	$39.18	0	1TM-Man 115,781
		78.36	1TM-Vol 156,361
Cost of HIV/AIDS Treatment	$119,274‡	59,637	1TM-Vol 79,036
		238,548	1TM-Vol 254,909
Procedures/Year	3,000	1,500	1TM-Vol 237,725
		6,000	1TM-Vol 90,494

* Our baseline value: 1TM-Vol $139,571 per prevented transmission. This assumes an average transmission rate scenario.
† As each parameter is varied all other parameters are held constant at their base value.
‡ These are total HIV/AIDS treatment costs. Costs are entered into the model according to stage (see description in text). For this sensitivity analysis costs for each stage were halved and doubled simultaneously, in effect halving and doubling total HIV/AIDS treatment costs.

most pronounced effect results from a change in the number of procedures performed per year (while all other variables are held constant). When the number of procedures for surgeons is halved, the cost per transmission prevented for a one-time voluntary screening program almost doubles. When the number of procedures doubles, the cost per transmission prevented for this program is roughly halved. For dentists, changes in the cost of HIV/AIDS treatment produces the most pronounced effect upon results. When the cost of treatment is halved, the cost per transmission prevented of a one-time voluntary screening program decreases 40% (to $79,036) and when the cost of treatment is doubled, the cost per transmission prevented increases 80% (to $254,909).

We also find that a one-time mandatory program dominates a one-time voluntary program (ie, is both cheaper and prevents more transmissions) for both surgeons and dentists when: 1) the percentage of infected surgeons or dentists who voluntarily test themselves decreases, 2) the percentage of uninfected surgeons or dentists who voluntarily test themselves increases, 3) the percentage of HIV-positive surgeons or dentists who refuse to reduce their risk of transmission increases, or 4) the cost of counseling decreases. In no cases were yearly screening programs more cost-effective than one-time screening programs.

DISCUSSION

We found one-time voluntary HIV screening programs of surgeons and dentists to be most cost-effective, costing about $899,336 and $139,571 per transmission prevented, respectively. We performed a cost-effectiveness analysis rather than a cost-benefit analysis because it allowed us to focus on preventing HIV transmissions, the most immediate goal of the screening programs, without introducing problematic estimates of the value of life. Likewise, we did not consider quality of life ramifications of screening programs which, while clearly important, merit an investigation that is beyond the scope of this analysis.

It is informative to compare our results with other studies that use the same effectiveness measure, HIV transmissions prevented. In a study examining the cost-effectiveness of screening healthcare workers, Phillips et al[30] obtained results consistent with an incremental cost-effectiveness of $326,000 per HIV transmission prevented for a one-time mandatory screening of surgeons and $563,000 for dentists.[31] The difference between these results and ours is due largely to the effectiveness attributed to voluntary screening programs and the incremental effectiveness of mandatory programs. Phillips et al[30] assume that fewer than half of practitioners would change their behavior after screening HIV positive in a voluntary program. The importance of this assumption points to an area where more research is needed.

One study by Eisenstaedt and Getzen[31] found that blood donor screening strategies cost $124,089 for every transfusion-transmitted case of HIV infection prevented. Schwartz et al[23] found, using modified screening strategies, that it cost $16,850 to identify an HIV-positive unit of blood in high-prevalence areas and $32,275 per unit identified in low-prevalence areas (assuming that each of these units results in a single case of HIV infection, these figures represent the costs of transmissions prevented). Mendelson and Sandler[32] provide an additional blood donor screening analysis. They found that adding a test for HIV antigen to current testing methodologies cost $18 million to $24 million for each additional transfusion-transmitted case of HIV prevented.

McKay and Phillips[33] analyzed mandatory premarital screening for HIV and found that it would cost between $70,000 and $127,000 for each case of HIV infection prevented. In an additional analysis, Stock et al[34] found that implementation of the CDC's universal precautions at a 450-bed, acute-care teaching hospital in Hamilton, Ontario, would cost $8 million per transmission to healthcare worker prevented.

The cost to prevent transmission of HIV using blood donor and premarital screening strategies is less than the cost of any of the surgeon or dentist screening programs we have considered in our model. The implementation of universal precautions in a hospital similar to that studied by Stock et al is more expensive than the one-time (mandatory or voluntary) screening strategies we analyzed. Considering the promotion of universal precautions and the suspension of several premarital screening programs, it is apparent that noneconomic factors have been important determinants of screening policy.

In a study similar to ours, Russo and LaCroix,[35] building upon the work of Gerberding,[36] found that mandatory screening in a San Francisco hospital would cost $780,000 annually and produce $58,080 to $83,635 in benefits. It is possible to calculate the number of transmissions prevented rather than dollar benefits from the Russo and LaCroix article. Doing so, we find that the expected cost-effectiveness of the mandatory screening program would range from $8.4 million to $83.6 million per prevented transmission at this hospital. The Russo and LaCroix study is limited, however, in that it only examined one hospital in San Francisco, only considered a mandatory screening scenario, used the same HIV transmission rate for both surgeons and dentists, and examined only the first year of the screening program.

CONCLUSIONS

We found that one-time screening programs, both voluntary and mandatory, were more cost-effective than annual screening programs. The annual screening programs detected the same cases as the one-time programs during the first year, but subsequent yearly screenings detect many fewer incident cases while continuing to incur large costs. Thus, while one-time programs prevented fewer total HIV transmissions than annual programs, they cost significantly less. The investment of healthcare resources in annual screening programs for surgeons and dentists is clearly an inefficient use of resources. One-time programs are expensive, but fall in the range of other programs to prevent transmissions of HIV.

The difference between mandatory and voluntary screening programs is less obvious than the difference between annual and one-time screening programs, but it accounts for substantial variation in program cost-effectiveness. In general, whether one-time voluntary or mandatory programs are preferred in our model for both surgeons and dentists depends on the number of infected practitioners at the beginning of the screening program, the proportion of infected surgeons or dentists who voluntarily test themselves, the proportion of uninfected surgeons or dentists who voluntarily test themselves, the proportion of HIV-positive surgeons or dentists who do not reduce their risk of transmission, and the cost of counseling.

Using liberal assumptions about these programs' effectiveness, none of the programs we considered was convincingly cost-effective and several represent notably poor use of resources. Our findings suggest that because of the wide variation in cost-effectiveness, the design of any screening program for healthcare practitioners—whether one-time or annual, voluntary or mandatory—must be scrutinized carefully before implementation.

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