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Relative Impact of Different Strategies for Allocating Federal Funds for Syphilis Prevention

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Abstract

Background: Improvements in resource allocation can increase the benefits of federally funded sexually transmitted disease (STD) prevention activities. The purpose of this study was to illustrate how different strategies for allocating federal funds to subnational districts for syphilis prevention might affect the incidence of syphilis at the national level.

Methods: We modeled syphilis rates by district and year using an equation based on a previous analysis of state-level syphilis elimination funding and syphilis case rates from 1998 to 2005 in the United States. We used the model to illustrate the potential impact of 3 different strategies for allocating supplemental federal funds to subnational districts to support syphilis prevention activities a hypothetical country with 18 subnational districts. The 3 strategies were based on each district's (1) population size, (2) syphilis incidence rate, or (3) number of syphilis cases. The hypothetical country was similar to the United States in overall population and syphilis burden.

Results: Without the supplemental federal funds, there would be an estimated 48,600 incident infections annually in the hypothetical country. With the supplemental federal funds, the annual number of infections would be reduced to 27,800 with a population-based allocation of funding to each district, 26,700 with a rate-based allocation, and 24,400 with a case-based allocation of funding.

Conclusions: Allocating federal STD prevention funds to districts based on burden of disease can be an efficient strategy, although this efficiency may be reduced or eliminated when high-burden districts have less ability to provide adequate STD prevention services than lower-burden districts.

When sexually transmitted disease (STD) prevention resources are not allocated efficiently, the resulting health and economic burden of STDs is greater than it would have been in the scenario of efficient allocation.¹ Accordingly, for reasons including improved efficiency, the distribution of federal funds to states and other project areas for STD prevention in recent years has been based on disease burden and population, under the STD AAPPs (Improving Sexually Transmitted Disease Programs through Assessment, Assurance, Policy

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Development, and Prevention Strategies) program.² Under the STD AAPPS funding formula, 50% of funding is based on the size of the population aged 15 to 44 years, and 50% of funding is based on the burden of STDs.

In the context of syphilis prevention, resource allocation can be defined as the process of distributing funds or resources among syphilis prevention interventions or activities that are competing for the same budget.³ Zaric and Brandeau⁴ describe a 2-level model of resource allocation for disease prevention: a higher-level allocation of funds (such as the federal-level decision of how to allocate syphilis prevention resources across states) and a lower-level allocation of funds (such as the decisions by STD officials in a given state regarding how to allocate their funding across different interventions and subpopulations). Efficient allocations are needed at both levels to ensure the greatest health benefit in terms of preventing syphilis and related sequelae.

As for the higher-level allocations of funds, there are numerous ways to determine how to allocate federal prevention funds across states and other jurisdictions. For example, the distribution of federal resources across states could be based on equity criteria, such as population size and disease burden. With a population-based allocation, all states would get the same amount of funding per capita. With a burden-based allocation, all states would get the same amount of funding per syphilis case.

The purpose of this study was to illustrate how the allocation of federal syphilis prevention resources across states might affect the incidence of syphilis at the national level. To do so, we developed a simple modeling approach based on the estimated impact of federally funded syphilis elimination activities from 1998 to 2005.⁵ We used the model to estimate the potential impact of the provision of supplemental federal funds for syphilis prevention activities in a hypothetical country, under different resource allocation strategies.

METHODS

We examined the provision of supplemental funds for syphilis prevention activities in a hypothetical country similar to the United States in terms of population and burden of primary and secondary syphilis. The hypothetical country consisted of 9 types of districts, created from 3 population size groups (6 million, 18 million, and 30 million) and 3 incidence rate groups (5, 15, and 25 incident infections per 100,000), as listed in Table 1. We created districts in this manner so that all combinations of population size and burden levels would be included. There were 2 of each type of district, for a total of 18 districts (e.g., district 1 corresponds to district 10, district 2 to district 11, and so on, as listed in Table 1). We created 2 of each type of district because in some analyses, we classified the districts into 2 groups according to the effectiveness of their syphilis prevention activities.

The total population we assumed of 324 million for the hypothetical country is consistent with recent estimates of the US population (www.census.gov). We assumed that in the absence of supplemental federal funds for syphilis prevention activities, all existing STD prevention activities would continue without change and that the annual burden of syphilis would remain constant at the district and national levels. Specifically, the burden of syphilis

that we assumed in the hypothetical country in the absence of the supplemental funding (48,600 incident infections annually across all districts) is in line with the 55,400 estimated number of incident infections in the United States in 2008,⁶ which includes all new infections (not just reported cases).

We assumed that the supplemental federal funds for syphilis prevention activities would be distributed at the district level. We assumed that the districts would continue their existing STD prevention activities and would use the supplemental funding to add new syphilis prevention activities or enhance existing activities. We examined the effect of the supplemental funding under 3 different resource allocation strategies. First, each district received the same amount of supplemental funding per capita (“population-based allocation”). Second, each district’s share of the supplemental funding was equal to that district’s syphilis incidence rate as a percentage of the sum of the syphilis incidence rates for all 18 districts (“rate-based allocation”). Third, each district’s share of the supplemental funding was equal to that district’s number of infections as a percentage of the number of infections in all districts (“case-based allocation”). For simplicity, we assumed that each district’s syphilis incidence rate was known with certainty. We assumed that the annual supplemental funding to be allocated was \$64.8 million, which is \$0.20 per capita nationwide.

In our approach, the incidence rate of syphilis (new infections per 100,000) in each district in the current year was calculated based on (1) the incidence rate of syphilis in that district in the previous year and (2) that district’s allocation (per capita) of the supplemental federal funds in the current year. To focus solely on the effect of each funding allocation strategy on the syphilis incidence after the supplemental federal funds were expended, we assumed that each district’s syphilis incidence rate would remain constant at its initial rate in the absence of the supplemental federal funds for syphilis prevention.

Examining the Effects of Different Resource Allocation Strategies if the Syphilis Prevention Programs in All Districts Are Equally Effective

We used the following expression to estimate the relative reduction in each district’s syphilis incidence rate attributed to the supplemental federal funds for syphilis prevention: $\exp^{(-2.79 \times F)} - 1$, where F is the change in the district’s per capita supplemental funding from the previous year and $\exp$ is the base of the natural logarithm ($\exp \sim 2.71828$). This formula was derived from a state-level analysis of the effect of federal funding allocations for various syphilis elimination activities from 1998 to 2005,⁵ which estimated that each 1-dollar increase in funding per capita was associated with a reduction of 2.79 in the natural log of the early syphilis rate. The value of -2.79 was derived by adjusting the published coefficient of -3.35 for inflation to 2016 dollars (see technical appendix, <http://links.lww.com/OLQ/A249>).

The application of this formula can be described with an example. If each district received \$0.20 per capita in supplemental funding for syphilis prevention, then $F = 0.20$ in the first year of the supplemental funding and the relative change in syphilis incidence would be $\exp^{(-0.558)} - 1$, or $0.572 - 1$, or -0.428 . In this example, the supplemental funding would decrease syphilis incidence by 42.8% in each district, and the new syphilis incidence rates

would hold steady in each subsequent year as long as each district received \$0.20 per capita per year in supplemental funding. Thus, in our simple approach, the effects of the supplemental funding are immediate and persist only for that year.

Examining the Effects of Different Resource Allocation Strategies if the Effectiveness of Syphilis Prevention Programs Varies Across Districts

To examine how the effect of different resource allocations might vary when the effectiveness of syphilis prevention activities varies across districts, we used the following expression to estimate the relative reduction in each district's syphilis incidence rate: $\exp^{[-2.79 \times F \times Q]} - 1$, where F and $\exp$ are as described earlier and Q is an adjustment factor to account for effectiveness of each district's prevention program. In this exercise, we assumed that 9 of the districts (districts 1–9) had highly effective syphilis prevention programs that could make efficient use of supplemental funding. We assumed the other 9 districts (districts 10–18) had less effective syphilis prevention programs that were unable to use the supplemental funding as efficiently. We set Q to 1.9 for the higher-performing districts (districts 1–9) and to 0.1 for the lower-performing districts (districts 10–18). Thus, the higher-performing districts were 90% more effective, and the lower-performing districts were 90% less effective, than the average district in the scenario in which we assumed syphilis prevention activities in all districts were equally effective.

For the scenario in which the districts differed in the effectiveness of their syphilis prevention activities, we assumed that the supplemental funding would have 2 phases (phase 1 and phase 2) and that funding allocation decisions would be made twice, once for each phase. Initially, the \$64.8 million in supplemental funding for phase 1 would be allocated as described in Table 1. For phase 2, funds were reallocated based on phase 1 results. That is, for phase 2, the rate-based and case-based allocations were reallocated based on the burden of syphilis in phase 1. The population-based allocations were the same in phase 2 as in phase 1, because the district populations were assumed not to change over time.

The purpose of this 2-phase approach was to illustrate a scenario in which a district's syphilis burden was inversely correlated with the effectiveness of its syphilis prevention activities. Specifically, in phase 1, each district with a less effective syphilis prevention programs (districts 10–18) would have a higher syphilis rate than its corresponding district with a more effective syphilis prevention program (districts 1–9). For example district 10 would have a higher syphilis rate in phase 1 compared with district 1, its corresponding district.

RESULTS

Effects of Different Resource Allocation Strategies if the Syphilis Prevention Programs in all Districts Are Equally Effective

Without the supplemental funding, the baseline burden of syphilis would continue at 48,600 infections annually in the hypothetical country. With the supplemental funding, the annual number of infections would be reduced to 27,816 when the funding was distributed to districts according to each district's population (Table 2). The annual number of infections

would be reduced to 26,709 when funding was distributed according to each district's syphilis rate, and 24,409 when funding was distributed according to each district's number of infections. These reductions in syphilis incidence correspond to percentage reductions of 42.8% for the population-based allocation, 45.0% for the rate-based allocation, and 49.8% for the case-based allocation (Fig. 1, left).

Effects of Different Resource Allocation Strategies if the Effectiveness of Syphilis Prevention Programs Varies Across Districts

Without the supplemental funding, there would be 48,600 syphilis infections annually. For the first phase of the supplemental funding, the annual number of infections would be reduced to 31,398 when the funding was distributed according to population, 31,323 when distributed according to syphilis rates, and 29,620 when distributed according to number of infections. As designed, the number of infections was lower in phase 1 in the higher-performing districts (districts 1–9) than in the lower-performing districts (districts 10–18). For example, consider districts 1 and 10, which initially were identical in terms of population and syphilis burden and differed only in the effectiveness of the syphilis prevention activities supported by the supplemental funding. In the population-based funding scenario, the annual number of infections decreased from 300 to 104 in district 1 and from 300 to 284 in district 10.

In the second phase of the supplemental funding, the total number of syphilis cases was unchanged (31,398) when funds were allocated by population, because the population-based funding allocations for phase 2 were the same as for phase 1 (Table 3, Fig. 2). However, the total number of syphilis cases increased from 31,323 in phase 1 to 36,489 in phase 2 when funds were reallocated according to syphilis rates. Similarly, the total number of syphilis cases increased from 29,620 in phase 1 to 36,253 in phase 2 when funds were reallocated according to number of infections. The reduction in syphilis incidence in the reallocation scenario (phase 2 vs. the scenario of no supplemental funding) was 35.4% for the population-based allocation, 24.9% for the rate-based allocation, and 25.4% for the case-based allocation (Fig. 1, right).

DISCUSSION

Our study yielded 2 main findings. First, allocating federal STD prevention funds to districts based on burden of disease can be an efficient strategy to target funds where they are most needed. This finding is consistent with a key principle of resource allocation in that the effectiveness of an intervention can often be improved by targeting the intervention to those at highest risk. Second, the efficiency of allocating funds to districts based on burden of disease will be reduced or eliminated when high-burden districts have less ability to provide adequate STD prevention services than do lower-burden districts. That is, if district-level inefficiency in STD prevention is a main reason for higher burdens of STDs, then allocating federal funds across districts based on burden of STDs could be less effective than a strategy of allocation based on population.

Given the uncertainties and difficulties in assessing the quality and impact of STD prevention services across districts,^{7,8} these 2 main findings highlight the potential benefits

of a hybrid strategy in which a district's allocation depends on both disease burden and population. A hybrid strategy offers potential gains in efficiency by incorporating disease burden, whereas the incorporation of population size helps to address equity issues and to limit the potential for overallocation of funds to inefficient districts. The STD AAPPs funding formula provides an example of a hybrid strategy, in which half of funding is based on the burden of STDs and half is based on population size. Future modeling efforts could be useful to examine the potential effects of alternate allocation formulas.

Our analysis focused on the effect of "higher-level" resource allocations, in which decisions were made about how to allocate federal funds across districts. We did not specifically address "lower-level" resource allocations, in which districts make decisions on how to use their allotted share of the federal funds. However, we did implicitly examine this issue in our analyses in which districts were assumed to differ in the effectiveness of their syphilis prevention activities. As indicated in these analyses, the national impact of federally funded syphilis prevention resources will be limited if districts do not make the most of their allocation. These findings are consistent with those of Zaric and Brandeau,⁴ who noted that lower-level resource allocation decisions (such as the interventions selected and the subpopulations to whom STD prevention services are focused) can be a more important determinant of health impact at the national level than higher-level resource allocations. Given the importance of resource allocation decisions at that state and local area, additional research and tools are needed to inform these decisions.

Mathematical models can be useful tools to help determine which populations to target and which interventions to implement. For example, mathematical modeling evidence was used to inform Australia's "National Gay Men's Syphilis Action Plan."⁹ The model examined the expected epidemiological impact of numerous potential interventions, and the interventions were considered in the context of acceptability by gay men. One of the key priorities identified by the model was the ongoing screening for syphilis as a part of routine HIV management and testing, along with more frequent testing for those with more than 20 partners in the last 6 months.

Allocating resources efficiently can be difficult for decision makers at the state and local levels, because of a lack of locally relevant models and cost-effectiveness studies to inform allocation decisions. Other potential challenges include a lack of available expertise in resource allocation, health economics, and program evaluation.^{10,11} Accordingly, the Centers for Disease Control and Prevention's STD AAPPs program highlights the importance of resource allocation decisions and offers guidance to overcome potential barriers.² Specifically, STD AAPPs notes that an important long-term goal is to increase access to STD services among the most at-risk populations. To support the cost-effective use of STD prevention resources, STD AAPPs "establishes specific activities, outputs and evidence-based interventions, and calls for robust evaluation plans."²

Improving resource allocation is not the only way to increase the yield of STD prevention resources. Efforts to improve the efficiency of a given allocation can yield notable gains as well. Activities such as program evaluation can help to inform improvements in program efficiency, thereby improving efficiency of given allocation of resources. Carter¹² provides

several examples of improvements to interventions through evaluation noting that “evaluation of all STD programs, large and small, is within reach.”

Our analysis is subject to important limitations. We used a simple model of the impact of syphilis prevention efforts, based on per-capita funding. Although our approach is evidence based and can provide illustrations of the benefits of targeting resources across jurisdictions, our approach also has important disadvantages. The simplicity of the approach allows for only general illustrations of the potential effects of syphilis prevention activities. As described in the technical appendix in more detail, our approach did not fully capture transmission dynamics. For illustrative purposes, we assumed that the effects of the supplemental funding would be immediate and would last only for 1 year. In reality, intervention effects can take longer than 1 year to achieve their full impact, and the effects of interventions can persist even after the intervention ends. Furthermore, the analysis on which our model is based was ecological and focused on syphilis elimination activities from 1998 to 2005.⁵ The syphilis epidemic has changed substantially since then and has become more concentrated in men who have sex with men.¹³ Another limitation to note is that the values we chose for the number of districts, the district population sizes, and the syphilis rates in each district were arbitrary. One could choose alternate values for these key factors such that the relative efficiencies of the 3 allocation strategies we examined would differ. Finally, for simplicity of illustration, we assumed that each district’s syphilis incidence is known with certainty. In reality, reported syphilis cases can underestimate the true burden of syphilis in each district. Differential ascertainment of cases across districts could affect the efficiency of burden-based allocations. For example, districts with the highest degree of underreporting might be underfunded relative to districts with more complete reporting of cases. However, potential inefficiencies arising from such underfunding could be offset completely or in part if a high degree of underreporting is indicative of lower program quality.

In conclusion, resource allocation decisions can be an important determinant of the effect of federally funded syphilis prevention activities. Allocating federal funds to state and local areas with the highest disease burden can lead to greater reductions in syphilis than allocations based on other factors such as population. However, allocating federal funds to jurisdictions with a high burden can be less efficient if the high burden of syphilis in a given jurisdiction can be attributed to the jurisdiction’s inability to provide adequate STD prevention services. Although the allocations to state and local areas can be important, the decisions of state and local programs on how to use their funds, and their ability to implement effective programs, can be even more important than the federal-level decisions. The development of syphilis transmission models could help to inform resource allocation decisions and thereby improve the efficiency of syphilis prevention activities in the United States at all levels, from national to local.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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Figure 1.

In the scenario in which districts varied in terms of the effectiveness of their syphilis prevention activities, half of the states were 90% more effective and half were 90% less effective than the average district in the scenario in which all districts were assumed to have equally effective activities. The results shown for the scenario in which districts varied in their effectiveness represent the reduction in the number of syphilis cases in phase 2 of the supplemental funding compared with the scenario of no supplemental funding. See Figure 2 and Table 3.

Figure 2.

In the scenario in which districts varied in terms of the effectiveness of their syphilis prevention activities, we assumed that the supplemental funding allocation decisions would be made twice, once for phase 1 and once for phase 2. Initially, the \$64.8 million in supplemental funding for phase 1 would be allocated as described in Table 1. For phase 2, funds were reallocated based on phase 1 results. That is, for phase 2, the rate-based and case-based allocations were reallocated based on the burden of syphilis in phase 1. For phase 2, the population-based allocations were the same as in phase 1, because the district populations were assumed not to change over time.

TABLE 1.

Description of 18 Districts in Hypothetical Country

District No.	Population	Baseline Syphilis Incidence Rate (New Infections Per 100,000)	Baseline No. Incident Infections	Population-Based Funding Allocation	Rate-Based Funding Allocation	Case-Based Funding Allocation
1	6 million	5	300	\$1,200,000	\$1,200,000	\$400,000
2	6 million	15	900	\$1,200,000	\$3,600,000	\$1,200,000
3	6 million	25	1500	\$1,200,000	\$6,000,000	\$2,000,000
4	18 million	5	900	\$3,600,000	\$1,200,000	\$1,200,000
5	18 million	15	2700	\$3,600,000	\$3,600,000	\$3,600,000
6	18 million	25	4500	\$3,600,000	\$6,000,000	\$6,000,000
7	30 million	5	1500	\$6,000,000	\$1,200,000	\$2,000,000
8	30 million	15	4500	\$6,000,000	\$3,600,000	\$6,000,000
9	30 million	25	7500	\$6,000,000	\$6,000,000	\$10,000,000
10	6 million	5	300	\$1,200,000	\$1,200,000	\$400,000
11	6 million	15	900	\$1,200,000	\$3,600,000	\$1,200,000
12	6 million	25	1500	\$1,200,000	\$6,000,000	\$2,000,000
13	18 million	5	900	\$3,600,000	\$1,200,000	\$1,200,000
14	18 million	15	2700	\$3,600,000	\$3,600,000	\$3,600,000
15	18 million	25	4500	\$3,600,000	\$6,000,000	\$6,000,000
16	30 million	5	1500	\$6,000,000	\$1,200,000	\$2,000,000
17	30 million	15	4500	\$6,000,000	\$3,600,000	\$6,000,000
18	30 million	25	7500	\$6,000,000	\$6,000,000	\$10,000,000
Total	324 million	15	48,600	\$64,800,000	\$64,800,000	\$64,800,000

The baseline syphilis incidence rate (number of infections per 100,000) is for the scenario of no supplemental funding. The baseline number of infections was calculated based on the population size and incidence rate. The funding allocations shown are for the scenario in which all districts are assumed to have equally effective syphilis prevention activities.

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TABLE 2.

Syphilis Incidence (Number of New Infections) in 18 Districts Under Various Resource Allocation Strategies for Supplemental Federal Funds for Syphilis Prevention, When All Districts Are Assumed to Have Equally Effective Syphilis Prevention Activities

District No.	No Supplemental Funds (Baseline)	Population-Based Allocation of Supplemental Funds	Rate-Based Allocation of Supplemental Funds	Case-Based Allocation of Supplemental Funds
1	300	172	172	249
2	900	515	169	515
3	1500	859	92	592
4	900	515	747	747
5	2700	1545	1545	1545
6	4500	2576	1775	1775
7	1500	859	1342	1245
8	4500	2576	3220	2576
9	7500	4293	4293	2959
10	300	172	172	249
11	900	515	169	515
12	1500	859	92	592
13	900	515	747	747
14	2700	1545	1545	1545
15	4500	2576	1775	1775
16	1500	859	1342	1245
17	4500	2576	3220	2576
18	7500	4293	4293	2959
Total	48,600	27,816	26,709	24,409

TABLE 3.

Syphilis Incidence (Number of New Infections) in 18 Districts Under Various Resource Allocation Strategies for Supplemental Federal Funds for Syphilis Prevention, When Districts Are Assumed to Differ in the Effectiveness of Their Syphilis Prevention Activities

District No.	No Supplemental Funds (Baseline)	Population-Based Allocation of Supplemental Funds		Rate-Based Allocation of Supplemental Funds		Case-Based Allocation of Supplemental Funds	
		Phase 1	Phase 2	Phase 1	Phase 2	Phase 1	Phase 2
1	300	104	104	104	160	211	200
2	900	312	312	37	717	312	493
3	1500	520	520	7	1434	256	914
4	900	312	312	632	588	632	599
5	2700	935	935	935	1438	935	1478
6	4500	1559	1559	769	2681	769	2742
7	1500	520	520	1213	1118	1053	998
8	4500	1559	1559	2382	2526	1559	2463
9	7500	2598	2598	2598	3995	1281	4570
10	300	284	284	284	274	294	291
11	900	851	851	761	706	851	825
12	1500	1419	1419	1135	1044	1367	1305
13	900	851	851	883	872	883	873
14	2700	2553	2553	2553	2466	2553	2476
15	4500	4256	4256	4100	3891	4100	3916
16	1500	1419	1419	1483	1472	1472	1456
17	4500	4256	4256	4352	4257	4256	4127
18	7500	7093	7093	7093	6851	6834	6526
Total	48,600	31,398	31,398	31,323	36,489	29,620	36,253

Syphilis prevention activities were 90% more effective in districts 1 to 9 and 90% less effective in districts 10 to 18, respectively, than in the scenario in which all districts were assumed to have equally effective syphilis prevention activities. After the first phase of the intervention, funds were reallocated. For the population-based allocation, phase 1 and phase 2 results are the same because the funding allocation in phase 2 is the same as in phase 1, because the district populations were assumed not to change over time. For the rate-based allocation of funds, funding in phase 2 is based on the rates in phase 1. For the case-based allocation of funds, funding in phase 2 is based on the cases in phase 1.