Research / Recherche

Evaluation of house-to-house versus fixed-site oral poliovirus vaccine delivery strategies in a mass immunization campaign in Egypt

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Among poliomyelitis eradication activities recommended by WHO are national immunization days. Most campaigns have delivered oral poliovirus vaccine (OPV) from fixed sites, reaching 80–90% of target populations. Although house-to-house vaccination provides nearly universal coverage, countries have been reluctant to use this approach because it is considered more costly and logistically difficult. To quantify the cost-effectiveness of both these strategies, we compared the vaccine coverage and vaccination costs per child for house-to-house and fixed-site delivery in a mass campaign in Egypt. While personnel and total costs were higher in house-to-house delivery (38% and 13% higher, respectively), the costs per child vaccinated were similar. This was due primarily to the high coverage levels achieved in house-to-house delivery (100% versus 86%) and the reduced vaccine wastage. Vaccinating children at highest risk of infection was only 25–50% as expensive on a per child basis using house-to-house delivery, since such children were less likely to visit fixed sites. These findings may not be generalizable to other countries where labour costs are higher and the population density lower; however, house-to-house delivery may prove to be the most cost-effective eradication strategy by ensuring universal access to immunization.

Introduction

In May 1988 the Forty-first World Health Assembly committed WHO to the global eradication of poliomyelitis by the year 2000 (*1*). Among immunization activities recommended in WHO's plan of action[a] are national immunization days: administration of oral poliovirus vaccine (OPV) to all children in an appropriate age group (usually <5 years of age), regardless of their prior immunization status. Ideally, mass campaigns should be conducted over a limited period (a few days to weeks), and preferably during the low season of poliovirus transmission. A second OPV dose is recommended 4–6 weeks after the first dose. This strategy was based primarily on the success achieved in the Region of the Americas, where wild poliovirus infection was eliminated within a period of approximately 5 years (*2*).

Mass immunization campaigns in most countries have delivered OPV at fixed immunization sites, and have reported covering 80–90% of target populations. Occasionally, house-to-house campaigns have also been used, and by their very nature provide nearly universal vaccine coverage. However, because house-to-house vaccine delivery has been considered more costly and more logistically difficult than fixed-site delivery, many countries have been reluctant to implement it.

In an effort to quantify better the relative cost-effectiveness of these two vaccine delivery strategies, we compared the vaccine coverage and per child vaccination costs for house-to-house and fixed-site OPV delivery in a mass immunization campaign conducted in Egypt in 1993. In addition, we evaluat-

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ed the characteristics of children vaccinated from fixed sites to identify children "at risk" of not participating in fixed-site mass campaigns.

Methods

All children aged 0–5 years inclusive were targeted to receive one dose of OPV in each of two rounds of vaccine delivery; no other vaccines were administered. To meet the objectives of the evaluation, two well-defined catchment areas were identified which were considered to be representative of other regions in Egypt; one of these was in an urban area and the other in a rural area. The OPV coverage in these catchment areas in 1992 was 86% and 88%, respectively, similar to the 89% coverage estimated for the whole of Egypt in 1992. In both areas, OPV was delivered from fixed sites in the first round of the mass campaign, and by house-to-house visits in the second round.

During both rounds, the age, sex, poliomyelitis vaccination histories, method of vaccine history confirmation (card/history), location (inside/outside the catchment area), and residence area (urban/rural) were recorded for each child on standardized forms. The costs associated with each round were calculated based on the number and type of health care personnel needed, cold chain requirements, and the number and size of OPV vials used.

In the first round, the locations of fixed vaccine delivery sites (four sites in the urban area and two sites in the rural area) were temporarily established so that the campaign would be evenly spaced throughout the catchment areas, providing the maximum number of children with easy access to vaccination. At mosques within both catchment areas announcements were made throughout each day for adults to bring their children to the sites for vaccination. OPV was administered each day from 10:00 until no additional children arrived for vaccination.

In the second round, house-to-house vaccine delivery was conducted in the catchment areas (non-catchment areas delivered vaccine from fixed sites). Street maps were obtained for both urban and rural catchment areas and each vaccination team was assigned a specific area to cover. These areas were then subdivided into six sub-areas to ensure that the entire area would be covered during the 6-day campaign. Teams then made door-to-door visits and vaccinated all eligible children. Households were re-visited repeatedly if eligible children were identified but absent when the teams called; thus, all eligible children were probably vaccinated during the 6-day vaccination period.

Statistical analysis

The vaccine coverage achieved in the first round was estimated in both the urban and rural catchment areas by calculating the proportion of eligible children enumerated in the house-to-house visits who reported having been vaccinated during this round, after excluding children who were younger than 1 month of age (i.e., those children not yet born during the first round). The costs per child vaccinated and the costs per high-risk child vaccinated[b] were calculated for each of the vaccine delivery strategies by summing the actual costs for health care personnel, cold chain equipment, and the number and size of vaccine vials; these costs were then divided by the number of children vaccinated to estimate the costs associated with each child vaccinated. Children were categorized into the number of doses they had received prior to the campaign, and the costs associated with vaccinating high-risk children were calculated.

In an effort to identify variables that may have been associated with not being vaccinated from fixed sites, vaccine coverage estimates were calculated for each of the variables collected on the standardized questionnaire in the second round, and χ^2 tests were then used to assess statistically significant differences.

Results

Vaccine coverage by type of vaccine delivery

Approximately 86% of children enumerated in both the urban and rural catchment areas in the second round reported having been vaccinated in the first round (Table 1). Because all eligible children who resided in the catchment areas in the second round were believed to have been enumerated, owing to the repeat household visits made by vaccination teams, vaccine coverage in the second round was assumed to be 100%. Differences between these vaccine coverage estimates were statistically significant ($P < 0.01$, χ^2 test).

Vaccine delivery costs

Overall costs were about 25% higher for house-to-house vaccination than for fixed-site vaccination in the urban area; costs in the rural area were similar (Table 2). More health care personnel and cold boxes were needed for house-to-house vaccination, particularly in the urban areas. In both vaccination rounds the cost of vaccine accounted for approximately 75% of the total cost of the campaign.

[b] High risk was defined as having received either zero or one dose of OPV prior to the mass campaign.

Table 1: **Coverage with OPV in the study population, by vaccination round and by catchment area, mass campaign, Egypt, 1993**

	No. vaccinated	Target population[a]	Vaccination coverage (%)
First round: fixed site delivery			
Urban	4 095[b]	4 747	86.3
Rural	1 931[b]	2 256	85.6
Second round: house-to-house delivery			
Urban	4 747	4 747	100
Rural	2 256	2 256	100

[a] Based on the number of eligible children enumerated in the catchment areas in the second round, after excluding children who were aged <1 month in the second round (i.e., children not yet born in the first round).
[b] Based on the proportion of eligible children enumerated in the catchment areas in the second round who reported having received a vaccine in the first round, after excluding children who were aged <1 month in the second round (i.e., not yet born in the first round).

Estimated cost of vaccine delivery per child

Although vaccination costs on a per child basis could be precisely determined for the second round, owing to the house-to-house enumeration of eligible children, those for the first round could not, because 24% (1570/6422) of the children vaccinated at the fixed sites reported living outside the catchment areas. Consequently, information collected in the house-to-house enumeration on first round participation was used to estimate costs. Although this information does not differentiate children vaccinated at fixed sites inside versus those outside the catchment areas, it none the less provides cost estimates consistent with the 86% observed coverage.

In the urban areas, the costs per child vaccinated at fixed sites were equivalent to the house-to-house vaccination costs (£E 0.37 (US$ 0.11) per dose), but were £E 0.10 (US$ 0.03) per dose higher in the rural areas (Table 3). In both the urban and rural areas, the costs of vaccinating children from fixed sites who reported having received zero or one dose of OPV prior to the campaign were approximately 2–4 times higher than the costs of house-to-house vaccination of these high-risk children. Although vaccine wastage in the urban areas was approximately 25% for both vaccine delivery strategies, in the rural areas wastage was nearly twice as high for fixed-site vaccine delivery (41.5%) than for house-to-house delivery (23.5%).

Table 2: **Total costs for OPV delivery, by catchment area, mass campaign, Egypt, 1983[a]**

	Fixed-site delivery:				House-to-house delivery:			
	Urban		Rural		Urban		Rural	
Expenditure	No.	Cost (US$)[b]	No.	Cost (US$)[b]	No.	Cost (US$)[b]	No.	Cost (US$)[b]
Personnel:								
Physicians	12	21.62	6	10.81	12	21.62	6	10.82
Nurses	12	16.22	12	16.22	24	32.43	18	24.32
Hygienists	12	18.02	0	0	12	18.02	0	0
Clerks	12	14.41	12	14.41	24	28.83	18	21.62
Community workers	18	16.22	18	16.22	24	21.62	18	16.22
Drivers	6	9.01	6	9.01	12	18.02	6	9.01
Subtotal		95.50		66.67		140.54		81.99
Vaccine vials:[c]								
20-dose	45	54.05	0	0	0	0	0	0
50-dose	93	279.28	66	198.20	128	384.38	59	177.18
Subtotal		333.33		198.20		384.38		177.18
Cold boxes[d]	0	0	0	0	24	0.30	18	0.30
Total costs (US$)		428.83		264.87		525.22		259.47

[a] Because the costs of one refrigerator, transportation, and publicity were the same in both the first and second rounds, they were not included in the cost estimates. Additionally, although 252 extra ice-packs were used in the house-to-house campaign (144 in the urban area and 108 in the rural area) the costs of ice-packs over the 6-day vaccination period were considered too small to estimate.
[b] US$1 = £E 3.33.
[c] Based on US$ 0.06 per dose of OPV.
[d] Costs were based on the price of one cold box (US$ 19.17) and on its estimated life (5-years' daily use by the immunization programme): the cost of each cold box was estimated to be US$ 0.01 per day.

Table 3: **Costs per child vaccinated, by type of delivery and by catchment area, mass campaign, Egypt, 1993**

	Fixed-site delivery:		House-to-house delivery:	
	Urban	Rural	Urban	Rural
No. of prior OPV doses received[a]				
0	24	2	190	74
1	110	40	169	98
≥2	3 961	1 889	4 364	2 084
Unknown	0	0	24	2
Cost per child vaccinated (US$)[b]	0.11	0.14	0.11	0.11
Cost per high-risk child[c] vaccinated (US$)	3.20	6.31	1.46	1.51
OPV wastage (%)	26.2	41.5	25.8	23.5
Total number vaccinated	4 095	1 931	4 747	2 256

[a] Received prior to either round.
[b] US$ 1.00 = £E 3.33.
[c] 0–1 OPV doses received prior to the vaccination campaign.

Variables associated with nonvaccination from fixed sites

Although fixed-site vaccine coverage estimates (Table 4) were similar in urban and rural areas and for males and females, there were statistically significant differences (P <0.01) for age at vaccination (youngest and oldest children were less likely to be vaccinated), the number of previous OPV doses reported (children with <3 prior OPV doses were less likely to be vaccinated), and the method of verification of vaccine history (children without vaccination cards were less likely to be vaccinated).

Discussion

Although the level of population immunity required to achieve elimination of wild poliovirus infection has not been determined, the emergence of large-scale outbreaks of poliomyelitis in highly vaccinated

Table 4: **Variables associated with vaccine receipt from fixed sites, mass campaign, Egypt, 1993**

Characteristic	No. vaccinated[a]	No. in target population[b]	Vaccination coverage (%)	*P*-value[c]
Location				
Urban	4 095	4 747	86.3	
Rural	1 931	2 256	85.6	0.45
Age range (months)				
1–11	854	1 062	80.4	
12–23	934	1 061	88.0	
24–35	1 065	1 184	90.0	
36–47	1 170	1 335	87.6	
48–59	1 239	1 420	87.3	
≥60	764	941	81.2	0.00
Sex				
Male	3 110	3 589	86.7	
Female	2 916	3 414	85.4	0.13
No. of prior OPV doses[d]				
0	26	140	18.6	
1	150	195	76.9	
2	222	266	83.5	
≥3	5 628	6 402	87.9	0.00[e]
Vaccine verification				
Card	1 035	1 131	91.5	
History	4 991	5 872	85.0	0.00
Total	6 026	7 003	86.1	

[a] Based on the proportion of eligible children enumerated in the catchment areas in the second round who reported having been vaccinated in the first round, after excluding children who were aged <1 month in the second round (i.e., children not yet born in the first round).
[b] Based on the number of eligible children enumerated in the catchment areas in the second round, after excluding children who were aged <1 month in the second round (i.e., children not yet born in the first round).
[c] By χ^2 test.
[d] Excluding doses received in the first round.
[e] By χ^2 test for linear trend.

populations in the Gambia (*3*), Oman (*4*), Jordan (*5*), and South Africa (*6*) suggests that only relatively small numbers of susceptible children are needed to sustain transmission. These observations, along with the results of serological surveys which indicate that up to 64% of children will fail to develop neutralizing antibody to poliovirus types 1 or 3 following routine administration of three doses of OPV (*7*), have reinforced the need to develop supplementary immunization strategies to minimize the number of susceptible children. Mass vaccination campaigns can achieve this goal in a number of ways, including the following: more aggressive efforts to vaccinate children who may have been missed in the routine programme; higher seroconversion rates than those achieved by routine delivery (*8*); repeated boosting of secretory antibody (which is generally short lived) in seropositive children; higher levels of immunity in the general population owing to intensive spread of vaccine virus to household and community contacts (*9–11*); and potential "displacement" of wild poliovirus following vaccination of large numbers of children simultaneously (*12*). These considerations, combined with the remarkable success of national vaccination days in Latin America (*2*), provide substantial support for the use of this approach in polio-endemic countries.

Because the principal goal of mass vaccination campaigns is to reduce the number of children who are susceptible to poliovirus infection, the effectiveness of campaigns depends primarily on the level of coverage achieved. Although house-to-house administration of OPV ensures that virtually 100% of children are vaccinated, many countries have been reluctant to implement this approach because it is perceived to be more labour intensive and costly than vaccination from fixed sites. Although these perceptions were borne out in the present study, where personnel and total costs were approximately 38% higher and 13% higher for house-to-house than for fixed-site delivery, respectively, the costs on a per child basis were similar for both approaches. This finding was due primarily to the higher levels of coverage achieved in house-to-house delivery (100% versus 86%), as well as the reduced vaccine wastage, particularly in rural areas. Of perhaps greater relevance was the observation that the cost of vaccinating children at highest risk of wild poliovirus infection (those with one or zero prior doses of OPV), was only one-quarter to one-half as expensive on a per child basis in the house-to-house campaign. The finding that such children are less likely to participate in a fixed-site campaign was also reported in a study in Cameroon, where most campaign participants had already been fully vaccinated in a routine programme (*13*).

Although in Egypt the costs involved in a house-to-house campaign were essentially offset by higher coverage rates, particularly for high-risk children, our findings may not be generalizable to other countries. First, the apparent cost advantages of house-to-house delivery in Egypt were due largely to very low expenses for labour; if such costs were only 2–4 times higher, as is the case in many other countries (*14*), the cost advantages of house-to-house delivery would largely disappear. Second, the population density in Egypt is high (1450 per km^2) (*15*), even in rural areas; this may also have resulted in lower costs for labour and supplies than those in other, less densely populated areas. Thus, in considering whether house-to-house campaigns should be implemented, the following factors, *inter alia*, must be evaluated: the local availability and cost of labour, transportation, and supplies; population density; the estimated number of high-risk children and the degree of difficulty in reaching them using routine immunization services or fixed-site campaigns; the desirability of providing vaccines other than OPV (often difficult to carry out in house-to-house campaigns); and the concern that parents may become more complacent in seeking immunization and other primary health care services for their children (*16*). Nevertheless, in view of the large and continuing burden of poliomyelitis among unvaccinated children in Egypt (Centers for Disease Control, Atlanta, GA, USA, unpublished data, 1993) and elsewhere (*17*), house-to-house delivery of OPV could very well prove to be the most cost-effective approach.

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Résumé

Comparaison des stratégies d'administration du vaccin antipoliomyélitique oral à domicile et dans des centres fixes lors d'une campagne de vaccination de masse en Egypte

Une des activités recommandées par l'OMS en vue de l'éradication de la poliomyélite est l'organisation de journées nationales de vaccination: tous les enfants de la tranche d'âge appropriée, quelle que soit leur situation vaccinale, reçoivent une dose de vaccin oral (VPO), suivie quatre à six

semaines plus tard d'une deuxième dose. Il est souhaitable que cette campagne de masse ne dure que quelques jours ou quelques semaines, de préférence pendant la saison où la transmission du poliovirus est ralentie. Le plus souvent, le VPO est administré dans des centres fixes qui touchent 80 à 90% de la population cible. Même si la vaccination à domicile assure une couverture presque totale, les pays hésitent à adopter cette méthode car ils estiment qu'elle est plus coûteuse et présente des difficultés logistiques.

Pour quantifier le rapport coût/efficacité de ces deux stratégies de vaccination, nous avons comparé la couverture et le coût par enfant de l'administration du VPO à domicile et dans des centres fixes lors d'une campagne de vaccination de masse en Egypte en 1993. En outre, nous avons évalué les caractéristiques des enfants vaccinés dans les centres fixes afin de déterminer ceux qui risquent d'être laissés à l'écart lorsque cette stratégie est retenue.

Deux secteurs bien définis et représentatifs (un secteur urbain et un secteur rural) ont été évalués. Dans ces deux secteurs, le VPO a été administré dans des centres fixes lors de la première phase de la campagne et à domicile au cours de la deuxième phase. Durant les deux phases, les informations pertinentes ont été recueillies pour chaque enfant vacciné. Pour calculer les coûts associés à chaque phase, on a pris en compte le nombre et la qualification des personnels de santé nécessaires, les besoins de la chaîne du froid, ainsi que le nombre et la contenance des flacons de VPO utilisés.

Malgré un coût en personnel et un coût total plus élevés pour la vaccination à domicile (respectivement 38% et 13% de plus), le coût par enfant vacciné a été comparable. Ce résultat est dû principalement à la couverture élevée de la vaccination à domicile (100% contre 86%) et à un moindre gaspillage de vaccin. La vaccination des enfants les plus exposés au risque d'infection (ceux qui n'avaient jamais été vaccinés ou qui n'avaient reçu qu'une dose de VPO avant la campagne) s'est révélée deux à quatre fois moins coûteuse par tête dans le cas de la vaccination à domicile, car ces enfants avaient moins de chance d'être vaccinés dans les centres fixes.

Bien que l'on ne sache pas exactement quel niveau doit atteindre le taux de vaccination dans la population pour éviter l'infection par le virus sauvage, les flambées importantes survenues dans des populations bien vaccinées, en Gambie, en Oman, en Jordanie et en Afrique du Sud, permettent de supposer qu'il suffit d'un nombre relativement faible d'enfants sensibles pour que la transmission du virus se poursuive. Ces observations, ainsi que les résultats d'enquêtes sérologiques selon lesquelles la proportion d'enfants ne produisant pas d'anticorps dirigés contre les virus de type 1 ou 3 après administration de trois doses de VPO peut atteindre 64%, confirment la nécessité de mettre au point des stratégies de vaccination complémentaires pour réduire au minimum le nombre d'enfants sensibles à l'infection. Etant donné que c'est là précisément le premier objectif des campagnes de vaccination de masse, leur efficacité dépend principalement du niveau de couverture atteint.

Les résultats de cette évaluation ne sont pas nécessairement applicables à d'autres pays où le coût de la main-d'œuvre est plus élevé et la densité de population plus faible; néanmoins, l'administration du VPO à domicile peut se révéler la stratégie la plus rentable pour l'éradication de la poliomyélite en assurant un accès universel aux services de vaccination.

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