**Appendix for a comparative cost analysis of the Vaccination Program for US-bound Refugees**

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# **Decision Tree**

The vaccination costs for US-bound refugees with and without the Vaccination Program for US-bound Refugees (VPR) were estimated using a simple decision tree model structure, stratified by age. We quantified and compared the costs for refugees to complete the age-specific Advisory Committee on Immunization Practices (ACIP)-recommended vaccination schedule using two scenarios: (1) a pre-2012 baseline without the VPR (‘No VPR’ scenario) and (2) the current situation with the VPR (‘VPR’ scenario). Under the ‘No VPR’ scenario, refugees only receive vaccines after resettlement in the United States and complete the age-specific ACIP-recommended schedule. Under the ‘VPR’ scenario, US-bound refugees received one or two doses of each vaccine provided by the VPR prior to departure and complete their age-specific vaccine schedules after resettlement in the United States.

Figure A1: Decision tree

**Domestic cost only**

By age and vaccine, numbers of doses to achieve full vaccination x Domestic vaccination cost per dose

Without the VPR

Decision

**Overseas cost**

By age and vaccine, numbers of doses administered from the VPR x Overseas vaccination cost per dose

With the VPR

+

**Domestic cost**

By age and vaccine, (Numbers of doses to achieve full vaccination by age – Numbers of doses administered from the VPR by age) x Domestic vaccination cost per dose

Notes: More details about numbers of doses given with and without the VPR are shown in Table A2-A5.

# **The number of doses to complete a series of all ACIP-recommended non-influenza vaccines per refugee and the number of doses of each vaccine provided by the VPR by age**

The numbers of doses of each vaccine recommended by the ACIP depends on age [1-3]. We subdivided refugees into four age groups based on the age when a refugee is able to start immunization: (1) infant to 4.9 years old, (2) 5 – 10.9 years old, (3) 11 – 18.9 years old, and (4) ≥19 years old. The analysis was simplified by assigning refugees to age categories and assuming that all refugees in each age category received the same number of doses of each vaccine. Although vaccine recommendations are different for adults >60 years compared to younger adults, only around 5% of refugees were 60 years or older in 2013[4]. To simplify the analysis, we assigned all adults to the recommended vaccination schedule for the 19-59.9 years old age group.

The vaccines provided by the VPR were chosen after taking into account disease risk and the cost and accessibility of vaccines in refugee camp and urban settings [5]. We took account the recommended U.S. immunization schedule from ACIP, the immunization schedule from the WHO Expanded Program on Immunization (EPI) and, the accessibility of vaccines in the countries implementing the VPR.

We included all ACIP-recommended non-influenza vaccines in the analyses (Table A1). The VPR does not include some of ACIP-recommended vaccines. Initially, the VPR provided one to two doses of the following seven vaccines: hepatitis B (HepB); diphtheria, tetanus, and pertussis (DTP); tetanus, diphtheria (Td); *Haemophilus influenzae* type b (Hib); Pentavalent (HepB-Hib-DTP); oral polio virus (OPV); and measles, mumps, and rubella (MMR). The VPR began providing the rotavirus vaccine to young children in 2016. However, most refugees are too old to be eligible for rotavirus vaccine so we excluded the rotavirus vaccine from our analysis. PCV13 is just beginning to be provided through the VPR in Kenya, and we do not have enough information about overseas vaccination cost. Thus, we excluded PCV13 from the VPR vaccine list for the analyses.

Table A1. List of examined vaccines and the availability of each vaccine in the United States and overseas.

|  |  |  |
| --- | --- | --- |
| Vaccine | United States | Overseas (VPR) |
| Diphtheria, tetanus, and acellular pertussis (DTaP) orDiphtheria, tetanus, and pertussis (DTP) | ˅ | ˅ |
| Tetanus, diphtheria, and acellular pertussis (Tdap)Tetanus, diphtheria (Td) | ˅˅ | ˅ |
| Hepatitis B (HepB) | ˅ | ˅ |
| *Haemophilus influenzae* type b (Hib) | ˅ | ˅ |
| Inactivated poliovirus (IPV) orOral poliovirus (OPV) | ˅ | ˅ |
| Measles, mumps, and rubella (MMR) | ˅ | ˅ |
| Hepatitis A (HepA) | ˅ |  |
| Human papillomavirus (HPV) | ˅ |  |
| Meningococcal conjugate vaccine (MCV4) | ˅ |  |
| Pneumococcal conjugate vaccine (PCV13) | ˅ |  |
| Varicella (VAR) | ˅ |  |

 Notes: DTaP and DTP are interchangeable. Also, IPV and OPV are interchangeable.

Refugees in the infant to 4.9 years old age group were expected to follow the ACIP-recommended catch-up immunization schedules for individuals aged 4 months through 6 years old [3]. We assumed that this age group was eligible for four doses of DTaP/DTP, three doses of OPV/IPV, and one dose of VAR (Table A2). As a result of the assumption that refugees would complete age-specific recommended catch-up schedule [3] within a 1-year time horizon, the fifth dose of DTaP/DTP, the fourth dose of OPV/IPV, and the second dose of VAR, which are available for children aged 4-6 years old, were not considered for this age group. The majority of refugee children in this age group (around 80%) are younger than 4 years old, using refugee age distributions from 2013 Yearbook of Immigration Statistics [4], and are not eligible for these doses.

A newborn infant following the ACIP-recommended vaccination schedule would require four doses of Hib to be fully vaccinated [3]. However, if the first dose of Hib is given after 15 months of age, additional doses are not recommended [3]. Since only 3-8% of refugees < 5 years are younger than 15 months old [4], we assumed that only one dose of Hib is required for this age group. One dose of PCV13 is recommended for healthy children aged 24 months to 59 months old who have not previously completed the PCV schedule. In comparison, four doses of PCV13 are required to achieve full vaccination in children between 6 weeks and 15 months [3]. For our analyses, we assumed that all refugees in this age group require one dose of PCV13 rather than four doses because more than 70% of arriving refugee children in this age group (infant to 4.9 year old) are ≥24 months old. We did not include rotavirus vaccine in our analyses because it is not recommended for children >8 months of age. Only 3% of refugees in the <5 years age group are <1 years old [4].

For vaccines that are part of a series, the goal of the VPR is to provide two doses of each vaccine for those who are eligible; the exception is DTP. The VPR provides only one dose of DTP to minimize the risk of adverse effects related to over-administration, because children may have received this vaccine in the past (e.g., in the refugee camp setting). The first doses of HepB, DTP, and Hib are provided in a combination (pentavalent) vaccine for this age group with the VPR.

Table A2: The number of doses for full vaccination (infant through 4.9 years old)

|  |  |  |
| --- | --- | --- |
| Vaccine | ‘No VPR’ scenario | ‘VPR’ scenario |
| US | Overseas | US |
| DTaP/DTP | 4 | 1 | 3 |
| HepB | 3 | 2 | 1 |
| Hib | 1 | 1 | 0 |
| IPV/OPV | 3 | 2 | 1 |
| MMR | 2 | 2 | 0 |
| HepA | 2 | N/A | 2 |
| PCV13 | 1 | 1 |
| VAR | 1 | 1 |
| Total | 17 | 8 | 9 |

Refugees in the 5-10.9 years age group and the 11-18.9 years age group are assumed to follow the ACIP-recommended catch-up immunization schedules for children aged 7-18.9 years old (Table A3-A4) [3]. We assumed that all refugees in each age category receive the same number of doses of each vaccine. The only exception was that DTaP/DTP is recommended for children aged 5-7 years and Tdap/Td is recommended for children ≥7 years. The estimated percentage of children who are 5-6.9 years old among all children in the 5-10.9 years of age category was 34% [4]. Thus, we assumed that the VPR provides one dose of DTP for 34% of children in the 5-10.9 years old group, and that 66% of the children in the 5-10.9 years old group receive two doses of Td overseas. In reality, however, children in the 7-10.9 years old group may receive less than two doses of Td from the VPR because only one dose of Td is given to children 7-10.9 years of age with history of any DTP, and Td vaccination is not given for those with a history of DTP vaccination within the past 12 months. For all other vaccines, we assumed that the VPR provides two doses of each vaccine for eligible children (Table A3).

Table A3: The number of doses for full vaccination (5-10.9 years old)

|  |  |  |  |
| --- | --- | --- | --- |
| Vaccine | Age subgroup | ‘No VPR’ | ‘VPR’ |
| US | Overseas | US |
| DTaP/DTP | 5-6.9 years (34%) | 4 | 1 | 3 |
| Tdap/Td | 7-10.9 years (66%) | 3 | 2 | 1 |
| HepB |  | 3 | 2 | 1 |
| IPV/OPV |  | 3 | 2 | 1 |
| MMR |  | 2 | 2 | 0 |
| HepA |  | 2 | N/A | 2 |
| VAR |  | 2 | 2 |
| Total | 5-6.9 years (34%) | 16 | 7 | 9 |
| 7-10.9 years (66%) | 15 | 8 | 7 |

Table A4: The number of doses for full vaccination (11-18.9 years old)

|  |  |  |
| --- | --- | --- |
| Vaccine | ‘No VPR’ scenario | ‘VPR’ scenario |
| US | Overseas | US |
| Tdap/Td | 3 | 2 | 1 |
| HepB | 3 | 2 | 1 |
| IPV/OPV | 3 | 0 | 3 |
| MMR | 2 | 2 | 0 |
| HepA | 2 | N/A | 2 |
| HPV | 3 | 3 |
| MCV4 | 2 | 2 |
| VAR | 2 | 2 |
| Total | 20 | 6 | 14 |

Refugees in the ≥19 years of age category were assumed to follow the ACIP-recommended US adult immunization schedule (Table A5) [2]. According to the ACIP-recommended vaccination schedule, HepB vaccination is only recommended for adults with risk factors [2]. However, since most US-bound refugees are travelers from countries of high or intermediate hepatitis B virus infection prevalence, we assumed that three doses of HepB would be recommended for all adult refugees. Two doses of MMR vaccination are recommended for full vaccination of adults born in or after 1957, according to the ACIP [2]. HPV is recommended for females aged 11-26 years old and males aged 11-21 years old in the United States [2]. Using the refugee age distribution, we estimated the percentage (18%) of the ≥19-years-old age group who are females between 19 and 26.9 years old or males between 19 to 21.9 years old and require HPV [4].

Table A5: The number of doses for full vaccination (≥19 years old)

|  |  |  |  |
| --- | --- | --- | --- |
|  Vaccine | Age subgroup | ‘No VPR’ scenario | ‘VPR’ scenario |
| US | Overseas | US |
| Tdap/Td |  | 3 | 2 | 1 |
| HepB |  | 3 | 2 | 1 |
| MMR |  | 2 | 2 | 0 |
| HPV  | Female aged 19-26.9 years old, or male aged 19-21.9 years (18%) | 3 | N/A | 3 |
| All others (82%) | 0 | 0 |
| VAR |  | 2 | 2 |
| Total | Female aged 19-26.9 years old, or male aged 19-21.9 years (18%) | 13 | 6 | 7 |
| All others (82%) | 10 | 6 | 4 |

# **Domestic vaccination costs**

After arrival in the United States, refugees are covered by either Medicaid or federally funded Refugee Medical Assistance (RMA) for at least 8 months [6]. Vaccine costs of most refugee children who are younger than 19 years old are covered by the Vaccines for Children (VFC) program and Medicaid. For adult refugees, most vaccination costs would be covered by RMA or Medicaid. Since RMA and Medicaid have similar reimbursement rates, we estimated base case vaccination costs for refugees based on Medicaid reimbursement rates and Medicaid beneficiaries’ out-of-pocket payment. For one-way sensitivity analyses, we developed lower- and upper-bound estimates. The lower-bound estimates were set equivalent to the base case Medicaid-based estimates. Private sector reimbursement rates were used to estimate upper bounds. For probabilistic sensitivity analyses, we generated gamma distributions of each cost estimate using the base case, lower-, and upper-bound estimates. Means and standard deviations of the distribution were calculated using the following formulas: Mean = (*Min* + 4×*Base* + *Max*)/6, Standard Deviation= (*Max* – *Min*)/6, where *Base* is our base case estimate, *Max* is our upper-bound estimate and *Min* is our lower-bound estimate [7].

1. **Vaccine costs**

**Refugees younger than 19 years old**

Vaccine costs for refugees younger than 19 years old are shown in Table A6. Base case costs of pediatric vaccines were estimated from CDC vaccine purchasing costs for the VFC using the average CDC purchasing costs per dose from January 5, 2015 and November 5, 2015, for each vaccine [8]. When there were multiple manufacturers per vaccine, we used a weighted average using the 2015 VFC purchasing data by supplier in 2015 (CDC internal data from Immunization Services Division) [9]. The upper-bound price estimate was calculated using the weighted average of private sector prices available from the VFC program website. We applied the same weighting by supplier that was used for the base case cost estimation. Since the VFC program is able to negotiate prices for bulk purchase, the lower-bound is the same as the base case. To account for potential vaccine expiration or accidental loss, a vaccine wastage rate of 5% [10] was added to the total number of vaccine doses required for cost estimation.

Table A6. Vaccine costs for refugees who are younger than 19 years old in the United States (2015 US dollars)

|  |  |  |  |
| --- | --- | --- | --- |
| Vaccine | Base case | Parameters for one-way sensitivity analyses | Parameters for probabilistic sensitivity analyses |
| Lower- bound | Upper- bound | Mean | Standard Deviation | Distribution |
| DTaP | 16.63 | 16.63 | 24.85 | 18.00 | 1.37 | Gamma |
| Tdap | 32.43 | 32.43 | 41.48 | 33.94 | 1.51 |
| Td | 19.17 | 19.17 | 24.44 | 20.05 | 0.88 |
| HepB | 11.76 | 11.76 | 23.19 | 13.67 | 1.91 |
| Hib | 11.08 | 11.08 | 26.7 | 13.68 | 2.60 |
| IPV | 13.15 | 13.15 | 29.52 | 15.88 | 2.73 |
| MMR | 20.43 | 20.43 | 62.44 | 27.43 | 7.00 |
| HepA | 17.47 | 17.47 | 30.73 | 19.68 | 2.21 | Gamma |
| HPV | 128.77 | 128.77 | 167.19 | 135.17 | 6.40 |
| MCV4 | 87.54 | 87.54 | 119.73 | 92.91 | 5.37 |
| PCV13 | 120.41 | 120.41 | 163.58 | 127.61 | 7.20 |
| VAR | 85.11 | 85.11 | 105.96 | 88.59 | 3.48 |

**Adult refugees (≥19 years old)**

Vaccine costs for adult refugees are shown in Table A7. Base case costs of adult vaccines were estimated using 2014 MarketScan Medicaid Multi-State Database outpatient files. The database covered more than 31 million Medicaid enrollees from 11 states in the United States [11]. The data were limited to Medicaid beneficiaries who were aged 19-59 years old with a fee-for-service plan. We excluded patients who were Medicaid-Medicare dual eligible and observations with zero payment records. We used the following Current Procedural Terminology (CPT) product codes to estimate costs by vaccine: 90715 (Tdap), 90714 (Td), 90746 (HepB), 90707 (MMR), 90649, 90650, 90651 (HPV), and 90716 (VAR) [12]. We used payment data, which include all gross payments (Medicaid reimbursement rates and Medicaid beneficiaries’ out-of-pocket payment) to a provider for a vaccine, to estimate the average costs of each vaccine. The average costs of each vaccine in 2014 were adjusted to 2015 costs using the average changes between 2014 and 2015 private sector vaccine prices reported on the VFC website [8].

The lower-bound and upper-bound prices were estimated using the CDC VFC Vaccine Price Archives [8]. The lower-bound estimates were negotiated government purchasing prices for uninsured or underinsured adults using the average of CDC purchasing price per dose (across suppliers and dates) on January 5, 2015 and November 5, 2015. The upper-bound estimates were calculated using the average of private sector costs per dose on January 5, 2015 and November 5, 2015 [8]. The rate of vaccine wastage was again assumed to be 5% for the lower- and the upper-bound estimates [10]. The base case vaccine cost estimates were not adjusted for wastage because MarketScan payment data only apply to vaccine doses delivered and should already include an offset for wastage.

Table A7. Vaccine costs for adult refugees (≥19 years old) in the United States (2015 US dollars)

|  |  |  |  |
| --- | --- | --- | --- |
| Vaccine | Base case | Parameters for one-way sensitivity analyses | Parameters for probabilistic sensitivity analyses |
| Lower- bound | Upper- bound | Mean | Standard Deviation | Distribution |
| Tdap | 38.01 | 23.85 | 41.67 | 36.26 | 2.97 | Gamma |
| Td | 20.72 | 14.44 | 22.18 | 19.92 | 1.29 |  |
| HepB | 51.92 | 26.93 | 59.15 | 48.96 | 5.37 |  |
| MMR | 44.82 | 40.96 | 62.43 | 47.11 | 3.58 |  |
| HPV | 138.41 | 99.29 | 152.57 | 134.25 | 8.88 | Gamma |
| VAR | 91.36 | 67.7 | 105.96 | 89.85 | 6.38 |  |

1. **Vaccine administration fee**

**Allowable charge units per dose for administration**

**Refugees younger than 19 years old**

We used CPT codes 90460 and 90461 to estimate vaccine administration fees for refugees younger than 19 years old. The CPT code 90460 is the immunization administration code of the first or only component of each vaccine for those who are younger than 19 years old, while CPT code 90461 is the code of each additional component of a combination vaccine beyond the first component for the same age group [13]. Thus, vaccine administration fees per dose vary depending on the number of components in each vaccine. For instance, a single dose of Tdap vaccination charges one unit of CPT 90460 and two units of CPT 90461 because Tdap consists of three components: tetanus, diphtheria, and acellular pertussis. The number of chargeable components per vaccine dose are shown in Table A8.

Table A8. Allowable charge units per dose for administration of each vaccine for refugees younger than 19 years old in the United States

|  |  |  |
| --- | --- | --- |
| Vaccines | CPT 90460 | CPT 90461 |
| DTaP | 1 | 2 |
| Tdap | 1 | 2 |
| Td | 1 | 1 |
| HepB | 1 | 0 |
| Hib | 1 | 0 |
| IPV | 1 | 0 |
| MMR | 1 | 2 |
| HepA | 1 | 0 |
| HPV | 1 | 0 |
| MCV4 | 1 | 0 |
| PCV | 1 | 0 |
| VAR | 1 | 0 |

**Adult refugees (≥19 years old)**

CPT codes 90471 and 90472 were used to estimate allowable vaccine administration fees for adult refugees. For adults, vaccine administration fees depend on the numbers of different vaccines received during a visit. CPT code 90471 is the immunization administration code of the first single or combination vaccine for those who are 19 years of age or older [13]. CPT code 90472 is the immunization administration code of each additional single or combination vaccine, and should be used in conjunction with CPT code 90471 [13] during a single visit. Unlike persons younger than 19 years old, the vaccine administration fee for a single-component vaccine is equivalent to the fee for a combination vaccine. As an example, when an adult receives three vaccines, Tdap, HepB, and MMR, during a visit, the one unit of CPT code 90471 and two units of CPT code 90472 would be charged. The number of recommended vaccines for adults depends upon the age at arrival by gender. A maximum of five different vaccines may be recommended for adults, all of which could be delivered during one visit. The costs associated with adult vaccine administration are minimized by providing as many doses as possible at each visit, such that more doses are charged with CPT code 90472 and fewer doses are charged with CPT code 90471. Thus, we assumed that a maximum of five vaccines could be given per visit. The estimated minimum of CPT code 90471 charges to achieve for full vaccination for adults are shown in Table A9.

Table A9. Allowable charge units of vaccine administration required for adult refugees in the United States

Female aged 19-26.9 years old or male aged 19-21.9 years

|  |  |  |  |
| --- | --- | --- | --- |
|  | ‘No VPR’ scenario |  | ‘VPR’ scenario |
|  | Visit 1 | Visit 2 | Visit 3 | Total |  | Visit 1 | Visit 2 | Visit 3 | Total |
| Vaccines |  |  |  |  |  |  |  |  |  |
| Tdap/Td | 1 | 1 | 1 | 3 |  | 1 | 0 | 0 | 1 |
| HepB | 1 | 1 | 1 | 3 |  | 0 | 1 | 0 | 1 |
| MMR | 1 | 1 | 0 | 2 |  | 0 | 0 | 0 | 0 |
| HPV | 1 | 1 | 1 | 3 |  | 1 | 1 | 1 | 3 |
| VAR | 1 | 1 | 0 | 2 |  | 1 | 1 | 0 | 2 |
| Total doses for each visit | 5 | 5 | 3 | 13 |  | 3 | 3 | 1 | 7 |
| Units of administration fee for each visit by CPT code |  |  |
| CPT 90471 | 1 | 1 | 1 | 3 |  | 1 | 1 | 1 | 3 |
| CPT 90472 | 4 | 4 | 2 | 10 |  | 2 | 2 | 0 | 4 |

All other adults

|  |  |  |  |
| --- | --- | --- | --- |
|  | ‘No VPR’ scenario |  | ‘VPR’ scenario |
|  | Visit 1 | Visit 2 | Visit 3 | Total |  | Visit 1 | Visit 2 | Total |
| Vaccines |  |  |  |  |  |  |  |  |
| Tdap/Td | 1 | 1 | 1 | 3 |  | 1 | 0 | 1 |
| HepB | 1 | 1 | 1 | 3 |  | 0 | 1 | 1 |
| MMR | 1 | 1 | 0 | 2 |  | 0 | 0 | 0 |
| VAR | 1 | 1 | 0 | 2 |  | 1 | 1 | 2 |
| Total doses for each visit | 4 | 4 | 2 | 10 |  | 2 | 2 | 4 |
| Units of administration fee for each visit by CPT code |  |  |
| CPT 90471 | 1 | 1 | 1 | 3 |  | 1 | 1 | 2 |
| CPT 90472 | 3 | 3 | 1 | 7 |  | 1 | 1 | 2 |

**Unit costs of vaccine administration**

The base case estimates of vaccine administration fees per vaccine delivered were estimated using vaccine administration fees for Medicaid beneficiaries in 2015. We were unable to obtain state-specific Medicaid reimbursement rates for vaccine administration fees. However, state-specific 2014 Medicaid-to-Medicare fee rates have been published [14] and 2014 Medicare allowable reimbursement rates are available from the Centers for Medicare and Medicaid Services[15]. Medicaid reimbursement rates were estimated using 2014 Medicare vaccine administration fees and the 2014 Medicaid-to-Medicare fee index. Then, 2014 reimbursement rates were adjusted to 2015 US dollars using medical care Consumer Price Index (CPI). The vaccine administration fees by CPT code were estimated using the following equation:

$$\sum\_{i=1}^{51}(MedicareAdmin\_{i}×MedicaidToMedicare\_{i}×Arrivals\_{i})×\frac{Medical Care CPI 2015}{Medical Care CPI 2014}$$

*i*: 50 states and District of Columbia (*i*=1,2, .. 51)

$MedicareAdmin\_{i}$: 2014 state-specific Medicare vaccine administration fee

$MedicaidToMedicare\_{i}$: Adjusted Medicaid-to-Medicare fee index for primary care in 2014 for each state

$Arrivals\_{i}$: Proportions of refugees arrivals of each state

We first multiplied the 2014 Medicare vaccine administration fee from each state by state-specific Medicaid-to-Medicare fee index for primary care in 2014 [14, 15]. The fee index compares each state’s average allowable physician fees for Medicaid beneficiaries with fee-for-service programs to Medicare fees for the same services in each state [14]. The index was developed to measure the impact of expiration of the primary care “fee bump” in Medicaid [14, 16]. The primary care “fee bump” was an increase of allowable Medicaid fees for primary care services to Medicare levels from January 1, 2013 to December 31, 2014, as a part of the Affordable Care Act [16]. As a result of this primary care “fee bump”, Medicaid reimbursement rates increased by 73% [16]. In 2015, however, the primary care fee bump expired and each state decided whether to continue supporting the fee increase using state funds or not. We adjusted the Medicaid-to-Medicare fee index to 1 for those states, which decided to extend the Medicaid primary care fee increase as of November 2014 [16]. Those states with extended “fee bumps” were Alabama, Alaska, Colorado, Connecticut, Delaware, Hawaii, Iowa, Maine, Maryland, Michigan, Mississippi, Nebraska, Nevada, New Mexico, and South Carolina [16].

The average weighted 2015 Medicaid vaccine administration fee was estimated using numbers of refugee arrivals by state in 2015 [17]. We multiplied the proportion of refugee arrivals in each state by the estimated state-specific Medicaid vaccine administration fee in 2015 and summed estimates of each state as we showed in the equation. Medical care CPI was used to adjust the fees to 2015 US dollars [18]. Although states may determine their own Medicaid reimbursement policy for vaccination administration, CPT code 90461 was not reimbursable for the VFC-supplied vaccines by the Centers for Medicare & Medicaid Services in 2015 [19]. Thus, for the base case and lower-bound estimates, we assumed zero payment for CPT code 90461. The upper-bound estimate was based on the midpoint of private sector allowable fee ranges reported in Healthcare Solutions’ *2015 Physicians’ Fee & Coding Guide* [13].

Table A10. Estimated vaccine administration fees for refugees in the United States (2015 US dollars)

|  |  |  |  |
| --- | --- | --- | --- |
|  | Base case | Parameters for one-way sensitivity analyses | Parameters for probabilistic sensitivity analyses |
| Lower- bound | Upper- bound | Mean | Standard Deviation | Distribution |
| <19 years old |   |   |   |   |   |
| CPT 90460 | 17.16 | 17.16 | 41.00 | 21.13 | 3.97 | Gamma |
| CPT 90461 | 0 | 0 | 26.50 | 4.42 | 4.42 |  |
| ≥19 years old |  |  |  |  |  |
| CPT 90471 | 17.16 | 17.16 | 39.00 | 20.80 | 3.64 | Gamma |
| CPT 90472 | 8.60 | 8.60 | 26.50 | 11.58 | 2.98 |  |

We estimated total vaccine administration fees per individual younger than 19 years old for full vaccination by multiplying the units (Table A8-A9), unit costs (Table A10), and numbers of doses required for full vaccination (Table A2-A5).

$$Total vaccine administration fee per person younger than 19 years old=\sum\_{j=1}^{N}((Unit90460\_{j}×AdminFee90460+Unit90461\_{j}×AdminFee90461)×Dose\_{j})$$

j: type of vaccines required per person by age

$Unit90460\_{j}$: Numbers of CPT 90460 units required per single dose of vaccine j (Table A8)

$Unit90461\_{j}$: Numbers of CPT 90461 units required per single dose of vaccine j (Table A8)

$AdminFee90460$: Vaccine administration fee of one unit of CPT 90460 (Table A10)

$AdminFee90461$: Vaccine administration fee of one unit of CPT 90461 (Table A10)

$Dose\_{j}$: Numbers of doses required for full vaccination of vaccine j (Table A2-A5)

Total vaccine administration fees per adult for full vaccination were estimated by using the following equation:

$$Total vaccine administration fee per person 19 years or older=Unit90471\_{k}×AdminFee90471+Unit90472\_{k}×AdminFee90472$$

k: age groups based on whether it requires HPV vaccination or not

$Unit90471\_{k}$: Numbers of CPT 90471 units required per person (Table A9)

$Unit90472\_{k}$: Numbers of CPT 90472 units required per person (Table A9)

$AdminFee90471$: Vaccine administration fee of one unit of CPT 90471 (Table A10)

$AdminFee90472$: Vaccine administration fee of one unit of CPT 90472 (Table A10)

# **Overseas vaccination costs**

IOM provided data to estimate overseas vaccination costs associated with the VPR. For the overseas vaccination through the VPR, high-quality vaccines are sourced from the United Nations Children’s Fund or from local manufacturers abiding by World Health Organization’s Good Manufacturing Practices [20]. We used the average vaccination budget (weighted by the forecasted number of US-bound refugees) from 21 countries in which the VPR was implemented in fiscal year (FY) 2017 as a base case to estimate the costs of overseas vaccination. The per-person costs of vaccinations from the VPR were calculated using the following equation:

$$Costs of vaccination per person (VPR)=\sum\_{l=1}^{M}\left(\left(VaxCost\_{l}+VarCost\right)×Dose\_{l}\right)+FixCost$$

*l*: index for type of vaccine

$VaxCost\_{l}$: VPR costs of vaccine *l*

$VarCost$: Variable program costs per dose

$Dose\_{l}$: Numbers of doses of vaccine *l* provided by VPR

$FixCost$: Fixed program costs per person

The budget data did not account for potential differences in pediatric and adult HepB vaccine prices for selected locations. For all other vaccines, the budget vaccine costs were the population weighted average of pediatric and adult vaccine costs. The budget included a vaccine wastage rate of 5%. For program costs, we assumed that there are two components: fixed and variable costs. The fixed cost is per person and is not affected by numbers of vaccine doses provided per person. For instance, the hepatitis B surface antigen (HBsAg) test is only given once per person by the VPR, and the test costs are independent of numbers of vaccine doses delivered per person. We calculated fixed costs from the sum of office costs, office overhead, and HBsAg test costs divided by the forecasted number of US-bound refugees covered by the VPR in FY 2017. Since the budget was based on medical caseloads, we estimated the number of US-bound refugees by assuming that 20% of medical caseloads were for re-examination and not for new patients. Variable program costs per dose delivered were calculated from the sum of budgeted staff, staff overhead, and non-vaccine operational costs divided by the estimated number of doses delivered by country. The 5% vaccine wastage rate was used to account for the number of doses delivered rather than the number of doses purchased in the variable administration cost per dose estimate.

The lower-bound and the upper-bound estimates are defined for one-way sensitivity analyses based on the country-specific estimates of the vaccine costs per dose, the fixed cost per refugee, and the variable cost per dose. The lower-bound estimate was based on the first quartile (25th percentile) and the upper-bound estimate was based on the third quartile (75th percentile) of costs from the VPR-implementing countries. Gamma distributions for probabilistic sensitivity analyses were estimated using the base case, lower-bound, and upper-bound estimates, as discussed above for domestic vaccine costs.

Costs of vaccines vary by country and region. African countries, such as Ethiopia, Kenya, Tanzania, and Uganda reported relatively low costs among all countries implementing the VPR. The costs of vaccines in African countries can be represented by the lower-bound estimates. The middle- range group includes Asian and the Middle East countries, such as Malaysia, Nepal, Thailand, Jordan, Iraq, and Egypt. The base case estimates can be a proxy for the costs of vaccines in Asian and the Middle East countries. The high costs group includes Eastern European countries, such as Russia, Ukraine, Slovakia, and Romania. The upper-bound estimates can stand for the costs of those countries in the high vaccine costs group. Vaccine administration are country-specific and do not show any regional trends.

Table A11: Vaccination cost with the Vaccination Program for US-bound Refugees (VPR), 2015 US dollars

|  |  |  |  |
| --- | --- | --- | --- |
|  | Base case | Parameters for one-way sensitivity analyses | Parameters for probabilistic sensitivity analyses |
| Lower- bound | Upper- bound | Mean | Standard Deviation | Distribution |
| Vaccine costs (per dose) |  |  |  |  |  |
| DTP | 3.94 | 0.21 | 12.29 | 4.71 | 2.01 | Gamma |
| Td | 0.80 | 0.13 | 1.54 | 0.81 | 0.24 |  |
| HepB | 2.12 | 0.18 | 5.51 | 2.36 | 0.89 |  |
| Hib | 9.36 | 7.77 | 12.09 | 9.55 | 0.72 |  |
| OPV | 1.07 | 0.15 | 4.43 | 1.48 | 0.71 |  |
| MMR | 3.28 | 1.09 | 7.49 | 3.62 | 1.07 |  |
| Pentavalent (DTP-Hib-HepB) | 10.29 | 1.84 | 20.53 | 10.59 | 3.12 |  |
| Program costs |  |  |  |  |  |
|  per capita cost | 5.11 | 4.36 | 9.81 | 5.77 | 0.91 | Gamma |
|  per dose cost | 4.44 | 3.56 | 8.49 | 4.97 | 0.82 |  |

Table A12: Estimation of variable program costs from FY 2017 VPR budget

|  |  |
| --- | --- |
| Total numbers of doses expected to provide (A) | 430,449 |
| Staff cost (B) | $1,245,002 |
| Staff overhead cost (C)= (B)×12% | $149,400 |
| Non-vaccine operational cost (excluding HBsAg cost) (D) | $518,900 |
| Total variable cost (E)= (B)+(C)+(D) | $1,913,302 |
| Variable cost per dose (F)=(E) / (A) | $4.44 per dose |

Table A13: Estimation of fixed program costs from FY 2017 VPR budget

|  |  |
| --- | --- |
| Medical caseload (A) | 86,400 |
| Proportion of medical re-exam among medical caseload (B) | 0.2 |
| Numbers of refugees (C)=(A)/((B)+1) | 72,000 |
| Office cost (D) | $199,601 |
| Office overhead cost (E)= (D)×12% | $23,953 |
| HBsAg cost (F) | $144,155 |
| Total fixed cost (G)= (D)+(E)+(F) | $367,709 |
| Per person fixed cost (H)=(G)/(C) | $5.11 per person |

# **Estimation of overall average vaccination costs per person**

After we estimated per capita costs of vaccination for the ‘No VPR’ and ‘VPR’ scenarios by age group, we used 2013 age-specific U.S. refugee data to estimate the fraction of arriving refugees in each age category to develop weighted average costs per person. The age distribution in Table A14 is based on the 2013 Yearbook of Immigration Statistics [4], which provided numbers of refugee arrivals in FY 2013 by age group in 5-year intervals [4]. We assumed a uniform age distribution inside of each age group. For instance, we assigned 20% of those who are in 10-14 year age group in the 2013 Yearbook to the 5 –10.9 years old age group and remaining 80% of them to the 11 – 18.9 years old age group in Table A14. The estimated weighted average costs of vaccination person are referred to as overall vaccination costs per person throughout the manuscript.

Table A14: Age distribution of refugee arrivals in FY 2013

|  |  |  |
| --- | --- | --- |
| Age group | n | Percentage |
| Infant to 4.9 years old | 6,493 | 9% |
| 5 – 10.9 years old | 8,411 | 12% |
| 11 – 18.9 years old | 10,142 | 15% |
| ≥19 years old | 44,862 | 64% |
| Total | 69,909 | 100% |

# **Summary of input parameters**

A summary of all input parameters used in the model is shown in Table A15. Details are already are provided in sections 2-4.

Table A15: Input parameters

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Description | Base case | Lower-bound | Upper-bound | Distribution | References |
| **Numbers of vaccine doses required per capita** |  |  |  |
| Without VPR, Domestic (US) |  |  |  |  |  |
|  Infant – 4.9 years old |  |  |  |  |  |
| DTaP | 4 | N/A | N/A | N/A | [3, 4] |
| HepB | 3 |  |  |  | Table A2 |
| Hib | 1 |  |  |  |  |
| IPV | 3 |  |  |  |  |
| MMR | 2 |  |  |  |  |
| HepA | 2 |  |  |  |  |
| PCV13 | 1 |  |  |  |  |
| VAR | 1 |  |  |  |  |
|  5 – 10.9 years old |  |  |  |  |  |
| DTaP (34%, 5 – 6.9 years) | 4 | N/A | N/A | N/A | [3, 4] |
| Tdap (66%, 7 – 10.9 years) | 1 |  |  |  | Table A3 |
| Td (66%, 7 – 10.9 years) | 2 |  |  |  |  |
| HepB | 3 |  |  |  |  |
| IPV | 3 |  |  |  |  |
| MMR | 2 |  |  |  |  |
| HepA | 2 |  |  |  |  |
| VAR | 2 |  |  |  |  |
|  11 – 18.9 years old |  |  |  |  |  |
| Tdap  | 1 | N/A | N/A | N/A | [3] |
| Td | 2 |  |  |  | Table A4 |
| HepB | 3 |  |  |  |  |
| IPV | 3 |  |  |  |  |
| MMR | 2 |  |  |  |  |
| HepA | 2 |  |  |  |  |
| HPV | 3 |  |  |  |  |
| MCV4 | 2 |  |  |  |  |
| VAR | 2 |  |  |  |  |
|  ≥ 19 years old |  |  |  |  |  |
| Tdap  | 1 | N/A | N/A | N/A | [2, 4] |
| Td | 2 |  |  |  | Table A5 |
| HepB | 3 |  |  |  |  |
| MMR | 2 |  |  |  |  |
| HPV (18%) | 3 |  |  |  |  |
| VAR | 2 |  |  |  |  |
| Description | Base case | Lower-bound | Upper-bound | Distribution | References |
| With VPR |  |  |  |  |  |
|  Infant – 4.9 years old |  |  |  |  |  |
|  Overseas |  |  |  |  |  |
| DTP | 1 | N/A | N/A | N/A | CDC internal  |
| HepB | 2 |  |  |  | data |
| Hib | 1 |  |  |  | Table A2 |
| OPV | 2 |  |  |  |  |
| MMR | 2 |  |  |  |  |
|  Domestic (US) |  |  |  |  |  |
| DTaP | 3 | N/A | N/A | N/A | [3, 4] |
| HepB | 1 |  |  |  | Table A2 |
| IPV | 1 |  |  |  |  |
| HepA | 2 |  |  |  |  |
| PCV13 | 1 |  |  |  |  |
| VAR | 1 |  |  |  |  |
|  5 – 10.9 years old |  |  |  |  |  |
|  Overseas |  |  |  |  |  |
| DTP (34%, 5 – 6.9 years) | 1 | N/A | N/A | N/A | CDC internal  |
| Td (66%, 7 – 10.9 years) | 2 |  |  |  | data |
| HepB | 2 |  |  |  | Table A3 |
| OPV | 2 |  |  |  |  |
| MMR | 2 |  |  |  |  |
|  Domestic (US) |  |  |  |  |  |
| DTaP (34%, 5 – 6.9 years) | 3 | N/A | N/A | N/A | [3, 4] |
| Tdap (66%, 7 – 10.9 years) | 1 |  |  |  | Table A3 |
| HepB | 1 |  |  |  |  |
| IPV | 1 |  |  |  |  |
| HepA | 2 |  |  |  |  |
| VAR | 2 |  |  |  |  |
| 11 – 18.9 years old |  |  |  |  |  |
|  Overseas |  |  |  |  |  |
| Td  | 2 | N/A | N/A | N/A | CDC internal  |
| HepB | 2 |  |  |  | data |
| MMR | 2 |  |  |  | Table A4 |
|  Domestic (US) |  |  |  |  |  |
| Tdap | 1 | N/A | N/A | N/A | [3, 4] |
| HepB | 1 |  |  |  | Table A4 |
| IPV | 3 |  |  |  |  |
| HepA | 2 |  |  |  |  |
| HPV | 3 |  |  |  |  |
| MCV4 | 2 |  |  |  |  |
| VAR | 2 |  |  |  |  |
|  ≥ 19 years old |  |  |  |  |  |
|  Overseas |  |  |  |  |  |
| Td  | 2 | N/A | N/A | N/A | CDC internal  |
| HepB | 2 |  |  |  | data |
| Description | Base case | Lower-bound | Upper-bound | Distribution | References |
| MMR | 2 |  |  |  | Table A5 |
|  Domestic (US) |  |  |  |  |  |
| Tdap | 1 | N/A | N/A | N/A | [2, 4] |
| HepB | 1 |  |  |  | Table A5 |
| HPV (18%) | 3 |  |  |  |  |
| VAR | 2 |  |  |  |  |
| **Units of vaccine administration required per capita** |  |  |  |
| Without VPR |  |  |  |  |  |
|  Infant – 4.9 years old |  |  |  |  |  |
|  CPT 90460 | 17 | N/A | N/A | N/A | [13] |
|  CPT 90461 | 12 |  |  |  | Table A8 |
|  5 – 10.9 years old | 34% | 66% |  |  |  |  |
|  CPT 90460 | 16 | 15 | N/A | N/A | N/A | [4, 13] |
|  CPT 90461 | 12 | 8 |  |  |  | Table A8 |
|  11 – 18.9 years old |  |  |  |  |  |
|  CPT 90460 | 20 | N/A | N/A | N/A | [13] |
|  CPT 90461 | 8 |  |  |  | Table A8 |
|  ≥ 19 years old | 18% | 82% |  |  |  |  |
|  CPT90471 | 3 | 3 | N/A | N/A | N/A | [4, 13] |
|  CPT90472 | 10 | 7 |  |  |  | Table A9 |
| With VPR |  |  |  |  |  |
| Infant – 4.9 years old |  |  |  |  |  |
| Overseas  | 8 | N/A | N/A | N/A | CDC internal  |
|  Domestic |  |  |  |  | data, [13] |
|  CPT 90460 | 9 |  |  |  | Table A8 |
|  CPT 90461 | 6 |  |  |  |  |
| 5 – 10.9 years old | 34% | 66% |  |  |  |  |
| Overseas  | 7 | 8 | N/A | N/A | N/A | CDC internal  |
| Domestic |  |  |  |  |  | data, [4, 13] |
|  CPT 90460 | 9 | 7 |  |  |  | Table A8 |
|  CPT 90461 | 6 | 2 |  |  |  |  |
| 11 – 18.9 years old |  |  |  |  |  |
| Overseas  | 6 | N/A | N/A | N/A | CDC internal  |
| Domestic |  |  |  |  | data, [13] |
|  CPT 90460 | 14 |  |  |  | Table A8 |
|  CPT 90461 | 2 |  |  |  |  |
|  ≥ 19 years old | 18% | 82% |  |  |  |  |
| Overseas  | 6 | 6 | N/A | N/A | N/A | CDC internal  |
| Domestic |  |  |  |  |  | data, [4, 13] |
|  CPT 90471 | 3 | 2 |  |  |  | Table A9 |
|  CPT 90472 | 4 | 2 |  |  |  |  |
| **Vaccine costs per dose (US dollar)** |  |  |  |  |
| Domestic (US) |  |  |  |  |  |
|  Children (<19 years old) |  |  |  |  |  |
| DTaP | 16.63 | 16.63 | 24.85 | gamma | [8-10] |
| Description | Base case | Lower-bound | Upper-bound | Distribution | References |
| Tdap | 32.43 | 32.43 | 41.48 | gamma | Table A6 |
| Td | 19.17 | 19.17 | 24.44 | gamma |  |
| HepB | 11.76 | 11.76 | 23.19 | gamma |  |
| Hib | 11.08 | 11.08 | 26.70 | gamma |  |
| IPV | 13.15 | 13.15 | 29.52 | gamma |  |
| MMR | 20.43 | 20.43 | 62.44 | gamma |  |
| HepA | 17.47 | 17.47 | 30.73 | gamma |  |
| HPV | 128.77 | 128.77 | 167.19 | gamma |  |
| MCV4 | 87.54 | 87.54 | 119.73 | gamma |  |
| PCV13 | 120.41 | 120.41 | 163.58 | gamma |  |
| VAR | 85.11 | 85.11 | 105.96 | gamma |  |
|  Adults (≥ 19 years old) |  |  |  |  |  |
| Tdap | 38.01 | 23.85 | 41.67 | gamma | [8, 10, 11] |
| Td | 20.72 | 14.44 | 22.18 | gamma | Table A7 |
| HepB | 51.92 | 26.93 | 59.15 | gamma |  |
| MMR | 44.82 | 40.96 | 62.43 | gamma |  |
| HPV | 138.41 | 99.29 | 152.57 | gamma |  |
| VAR | 91.36 | 67.70 | 105.96 | gamma |  |
| Overseas |  |  |  |  |  |
| DTP | 3.94 | 0.21 | 12.29 | gamma | CDC internal |
| Td | 0.80 | 0.13 | 1.54 | gamma | Data |
| HepB | 2.12 | 0.18 | 5.51 | gamma | Table A11 |
| Hib | 9.36 | 7.77 | 12.09 | gamma |  |
| OPV | 1.07 | 0.15 | 4.43 | gamma |  |
| MMR | 3.28 | 1.09 | 7.49 | gamma |  |
| Pentavalent (HepB-Hib-DTP) | 10.29 | 1.84 | 20.53 | gamma |  |
| **Vaccine administration costs (US dollar)** |  |  |  |
| Domestic US |  |  |  |  |  |
| Children (<19 years old) |  |  |  |  |  |
| CPT 90460 | 17.16 | 17.16 | 41.00 | gamma | [13-16, 18, 19] |
| CPT 90461 | 0 | 0 | 26.50 | gamma | Table A10 |
| Adults (≥ 19 years old) |  |  |  |  |  |
| CPT 90471 | 17.16 | 17.16 | 39.00 | gamma | [13-16, 18, 19] |
| CPT 90472 | 8.60 | 8.60 | 26.50 | gamma | Table A10 |
| Overseas |  |  |  |  |  |
| Per capita cost | 5.11 | 4.36 | 9.81 | gamma | CDC internal |
| Per dose cost | 4.44 | 3.56 | 8.49 | gamma | data, Table A11 |
| **Proportion of refugee arrivals by age group (%)** |  |  |  |
| Infant – 4.9 years old | 9 | N/A | N/A | N/A | [4] |
| 5 – 10.9 years old | 12 |  |  |  | Table A14 |
| 11 – 18.9 years old | 15 |  |  |  |  |
| ≥ 19 years old | 64 |  |  |  |  |

# **Sensitivity Analyses**

To conduct probabilistic sensitivity analyses, we used gamma probability distributions, which are commonly used for positive real numbers. All inputs for the analyses were zero or positive real numbers. From mean and standard deviation estimated in the previous sections, we derived the following parameters:

 $α=\frac{Mean^{2}}{Standard Deviation^{2}}$

 $β=\frac{Standard Deviation^{2}}{Mean}$

We used @Risk software Version 7.5.0 to fit distributions. We performed sensitivity analyses using data from the Monte Carlo Simulation with 10,000 iterations.

# **Break-even analyses**

For the base case analysis, we assumed all refugees would complete the age-specific, non-influenza ACIP-recommended vaccination schedules after arrival. However, we anticipated that some refugees might not complete the ACIP-recommended schedule after arrival in the United States. In addition, some refugees might be unnecessarily revaccinated after arrival in the United States because some healthcare providers might not consider doses provided overseas to be valid. As part of the sensitivity analysis, we conducted break-even analyses to answer the following questions:

1. When refugees do not complete the ACIP-recommended schedule after arriving in the United States, can the VPR remain a cost-saving strategy? This break-even analysis will consider both the total costs and total numbers of vaccine doses provided.
2. If some refugees are unnecessarily revaccinated after arrival, can the VPR remain a cost-saving strategy from the US payers perspective?

To answer the first question, we varied the post-arrival coverage rate between 0% and 100% completion of the ACIP-recommended vaccination schedule after arrival. For instance, at a domestic coverage rate of 50%, refugees would receive 1.5 doses of a three-dose schedule (e.g., hepatitis B) on average (three doses × 50% coverage) with the ‘No VPR’ scenario. In comparison, for the ‘VPR’ scenario, a refugee would receive two doses from the VPR prior to departure. This refugee would only need to receive one dose after arriving to complete the three-dose schedule. If the coverage rate is 50%, then refugees would receive one dose needed x 50% coverage = 0.5 domestic doses, on average, after arrival. The total number of doses received under the ‘VPR’ scenario would then be two doses from the VPR + 0.5 domestic doses = 2.5 doses in total on average. Assuming equivalent domestic coverage rates for the ‘VPR’ and ‘No VPR’ scenarios, we identified the domestic coverage rate for which the US government costs, with and without the VPR, were equivalent, and estimated the numbers of doses of each vaccine received by refugees at the break-even domestic coverage rate. To answer the second question, we varied the revaccination rate from 0% (no domestic re-vaccination) to 100% (none of the doses provided overseas are considered valid in the United States) and investigated the range of government costs and the break-even re-vaccination rate at which the US governments’ costs, with and without the VPR, were equivalent.

# **Costs comparison between with and without the Vaccination Program for US-bound Refugees using private sector costs for domestic vaccination costs**

Table A16: Costs of full vaccination, except for influenza, with and without the Vaccination Program for US-bound Refugees (VPR), by age group using private sector costs for domestic vaccination costs (2015 US dollars)

All vaccines except influenza vaccines

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | ‘No VPR’ scenario (a) | ‘VPR’ scenario | Net cost savings(a)-(b) | Percent cost reduction$\frac{\left(a\right)-(b)}{(a)}$ (%) |
| Total (b)=(c)+(d) | Domestic (c) | Overseas (d) |
| Infant to 4.9 years old | 1,755.11 | 1,039.12 | 986.26 | 52.86 | 715.99 | 40.8% |
| 5-10.9 years old | 1,526.80 | 837.19 | 782.73 | 54.45 | 689.61 | 45.2% |
| 11-18.9 years old | 2,419.78 | 1,838.79 | 1,794.64 | 44.15 | 580.99 | 24.0% |
| ≥19 years old | 999.46 | 586.84 | 542.69 | 44.15 | 412.62 | 41.3% |
| Overall | 1,343.80 | 845.38 | 799.21 | 46.17 | 498.42 | 37.1% |

Vaccines provided by the VPR only (DTaP/DTP/Tdap/Td, HepB, Hib, IPV/OPV, and MMR)

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | ’No VPR’ scenario (a) | ‘VPR’ scenario | Net cost savings(a)-(b) | Percent cost reduction$\frac{\left(a\right)-(b)}{(a)}$ (%) |
| Total (b)=(c)+(d) | Domestic (c) | Overseas (d) |
| Infant to 4.9 years old | 1,260.11 | 544.12 | 491.26 | 52.86 | 715.99 | 56.8% |
| 5-10.9 years old | 1,089.42 | 399.81 | 345.35 | 54.45 | 689.61 | 63.3% |
| 11-18.9 years old | 1,036.37 | 455.38 | 411.23 | 44.15 | 580.99 | 56.1% |
| ≥19 years old | 635.59 | 222.97 | 178.82 | 44.15 | 412.62 | 64.9% |
| Overall | 806.37 | 307.96 | 261.79 | 46.17 | 498.42 | 61.8% |

Notes: DTaP, diphtheria, tetanus, and acellular pertussis; DTP, diphtheria, tetanus, and pertussis; Tdap, tetanus, diphtheria, and acellular pertussis; Td, tetanus, diphtheria; HepB, hepatitis B; Hib, *Haemophilus influenzae* type b; IPV, inactivated poliovirus; OPV, oral polio virus; MMR, measles, mumps, and rubella.

# **Cost comparison by type of costs**

The comparison of main vaccines provided by the VPR are shown in the Table A17.

Table A17: Cost comparisons of major vaccines provided by the VPR

|  |  |  |
| --- | --- | --- |
| Vaccine costs per dose | Domestic | Overseas |
| Children | Adults |
| DTaP/DTP | 16.63 | N/A | 3.94 |
| Td | 19.17 | 20.72 | 0.80 |
| HepB | 11.76 | 51.92 | 2.12 |
| IPV/OPV | 13.15 | N/A | 1.07 |
| MMR | 20.43 | 44.82 | 3.28 |

We compared the weighted average costs per person for vaccines delivered with the VPR and associated administration costs to the weighted average costs per person for same vaccines and services in the United States. The overseas vaccination costs with the VPR are $46.17 per person including $13.54 per person for vaccine costs and $32.63 per person for administration costs (Table A18). When the same doses of selected vaccines are provided in the United States, the vaccination costs would be $272.10 per person including $191.01 of vaccine costs per person and $81.09 of administration costs per person.

Table A18: Weighted average costs of vaccination (vaccines + administration) per person for vaccines provided overseas by the VPR compared to costs of providing the same doses domestically after arrival

|  |  |  |  |
| --- | --- | --- | --- |
| Type of costs | Overseas (A) | Domestic(B) | Difference(B)-(A) |
| Costs of vaccines |  |  |  |
| DTaP/DTP/Td | 1.86 | 37.48 | 35.62 |
| HepB | 4.36 | 74.92 | 70.56 |
| Hib | 0.31 | 1.00 | 0.69 |
| IPV/OPV | 0.45 | 5.52 | 5.07 |
| MMR | 6.56 | 72.08 | 65.52 |
| Total vaccine costs (C) | 13.54 | 191.01 | 177.47 |
| Administration costs (D) | 32.63 | 81.09 | 48.46 |
| Total (C)+(D) | 46.17 | 272.10 | 225.03 |

# **A comparison of annual refugee vaccination costs and potential cost savings of the VPR**

In FY 2017, approximately 50,000 refugees will be resettled in the United States [21]. It is a reduction from the 69,933 refugees resettled in FY 2015 [22]. For FY 2016, an estimated 72% of resettled refugees traveled from countries with the VPR in place, although coverage varies from year to year depending on the countries from which refugees are resettled. The results in Table A18 summarize annual refugee vaccination costs for the current situation (72% of arriving refugees from countries with the VPR) and an estimate of the additional cost to achieve 100% coverage for 50,000 refugee arrivals per year with the current VPR schedule (one or two doses of DTaP/DTP/Tdap/Td, HepB, Hib, IPV/OPV, and MMR). In this table, we directly compared the cost of the VPR to providing the same doses after domestic arrival and do not consider the full cost to complete the ACIP-recommended schedule.

Annual vaccination costs for refugees to provide the same subset of VPR vaccines (overseas and domestically) were estimated by multiplying vaccination costs per person and numbers of refugee arrivals per year. Domestic vaccination costs per refugee were $272.10 per person using Medicaid/RMA payments ($406.66 - $134.56 from Table 1) or $544.59 per person using private sector payments ($806.37 - $261.79 from Table A16). We assumed that the average overseas cost per refugee to extend the VPR to reach the last 28% of arriving refugees ($94.83 per person using upper-bound cost parameters) would be greater than the average cost per refugee previously analyzed ($46.17 per person from Table 1). We expect that the expansion of the VPR to additional countries would have higher vaccine purchase, operational, and logistics costs relative to countries currently covered by the VPR. The first row in Table A18 shows the annual costs for 72% refugee coverage, i.e., 36,000 refugees (50,000 x 0.72). The second row shows the marginal cost to reach the remaining 14,000 refugees and achieve 100% coverage.

The ratio of domestic costs to overseas costs varied from 6.1 to 12.3 for the current VPR schedule with 72% coverage. Because of the higher overseas cost per refugee to cover the remaining 28% of refugee arrivals, the ratio would decline slightly for 100% coverage (4.7 to 9.4).

Table A18: Annual vaccination costs for pre-departure costs (VPR) vs. post-arrival domestic costs to provide the same subset of vaccines (50,000 refugees)

|  |  |  |  |
| --- | --- | --- | --- |
|  | Domestic (2015 million US$) | Overseas(2015 million US$, C) | Ratio of domestic costs to overseas costs |
| Medicaid/RMA payments (A) | Private sector payments (B) | Medicaid (A/C) | Private sector(B/C) |
| Current programs of 72% refugee coverage (D) | 9.8 | 19.6 | 1.6 | 6.1 | 12.3 |
| Marginal cost to reach 100% refugee coverage (E) | 3.8 | 7.6 | 1.3 | 2.9 | 5.8 |
| Total (D+E) | 13.6 | 27.3 | 2.9 | 4.7 | 9.4 |

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