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Deficiencies in Current Childhood Immunization Indicators

SYNOPSIS

Objective. To investigate "up-to-date" and "age-appropriate" indicators of preschool vaccination status and their implications for vaccination policy.

Methods. The authors analyzed medical records data from the Baltimore Immunization Study for 525 2-year-olds born from August 1988 through March 1989 to mothers living in low-income Census tracts of the city of Baltimore.

Results. While only 54% of 24-month-old children were up-to-date for the primary series, indicators of up-to-date coverage were consistently higher, by 37 or more percentage points, than corresponding age-appropriate indicators. Almost 80% of children who failed to receive the first dose of DTP or OPV age-appropriately failed to be up-to-date by 24 months of age for the primary series.

Conclusions. Age-appropriate immunization indicators more accurately reflect adequacy of protection for preschoolers than up-to-date indicators at both the individual and population levels. Age-appropriate receipt of the first dose of DTP should be monitored to identify children likely to be underimmunized. Age-appropriate indicators should also be incorporated as vaccination coverage estimators in population-based surveys and as quality of care indicators for managed care organizations. These changes would require accurate dates for each vaccination and support the need to develop population-based registries.

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Since the 1950s, two strategies have been used to monitor the control of vaccine-preventable childhood infectious diseases: disease surveillance and assessment of vaccination coverage rates. Disease surveillance was the more important strategy when these diseases were widely prevalent and the success of vaccination programs was measured by a reduction in the number of cases of disease. However, as the prevalence of vaccine-preventable diseases declined, the importance of vaccination coverage rates as indicators of the population's susceptibility gradually increased.[1] Vaccination coverage rates are now the most commonly used measure of the U.S. population's protection against vaccine-preventable diseases.

The vaccination status of children at age 2 years (up-to-date at 24 months) is the most widely accepted single index of the adequacy of preschool immunization coverage.[2] This index measures whether children have received a given vaccine, or the recommended series of vaccines, by the age of 2 years. The currently recommended series is four doses of diphtheria vaccine, tetanus toxoid, and pertussis vaccine (DTP); three doses of polio vaccine; three doses of *Hemophilus influenzae* type b vaccine (Hib); and one dose of measles, mumps, and rubella vaccine (MMR) at specific intervals from birth through 18 months of age.[2] Up-to-date at 24 months has been widely adopted by managed care organizations as a measure of the quality of their immunization practices, and it is included for the same purpose in the Health Plan Employer Data Information Set (HEDIS),[3] a set of standardized measures developed by the National Committee for Quality Assurance to assess the receipt of recommended health services among subscribers of managed care organizations and health plans.

The United States Immunization Survey (USIS) was a nationwide survey of vaccination levels conducted by the Centers for Disease Control and Prevention (CDC) between 1959 and 1985.[4] The USIS reported vaccination coverage separately for preschoolers younger than 1 year of age and those 1–4 years of age.[1] The CDC first proposed the widespread use of up-to-date at 24 months in 1972, as an early indicator of school-entry vaccination coverage rates. At that time the CDC was primarily interested in immunization coverage at school entry because measles, which is highly contagious, occurred mainly among school-age children. Measurement of coverage at age 2 years was promoted as an early and efficient predictor of school-entry coverage rates because researchers had found that measles and rubella vaccination levels rose sharply until age 24 months followed by a much slower rise until age 5, with a small jump just before school entry.[5]

The CDC initiated the National Health Interview Survey (NHIS) in 1991, after nationwide measles outbreaks in 1989, 1990, and 1991 demonstrated that vaccination coverage was inadequate. Given that half of these measles cases occurred in preschool children,[6] it was apparent both that the epidemiology of the disease had changed and that vaccination coverage in the first two years of life was low.[7] The NHIS adopted up-to-date at 24 months as a measure of vaccination success among preschoolers.

Partly to ensure sufficient sample size, the NHIS now collects data on the vaccination status of children ages 19 months through 35 months.[2] This modification of up-to-date at 24 months is now the main indicator of the adequacy of preschool vaccination coverage, both at the national and regional levels.

With the current attention to preschool vaccination coverage, it is timely to examine whether up-to-date at 24 months is the best indicator of preschool vaccination coverage. To do this, we compared up-to-date at 24 months with alternative indicators of immunization coverage, using data from a population survey of inner-city preschool children in Baltimore. Our findings have implications for the current debate over survey-based data versus the need for vaccination registries.

METHODS

Data for this analysis come from the Baltimore Immunization Study (BIS) conducted by Guyer et al. in 1991–1992.[8-15] Children eligible for this community-based study were born from August 1, 1988, through March 31, 1989, to women residing in the 57 Census tracts of Baltimore in which at least 50% of the resident births in 1987 were to mothers eligible for Medicaid.

From the eligible children, the BIS first excluded children who weighed less than 500 grams at birth, children who had died, and children who had been adopted prior to the survey. From the remaining 2489 eligible children, 1100 were then randomly selected. By the survey termination date, the primary caregiver (henceforth referred to as the parent) of 735 children had been located and 557 had been interviewed. The study found no significant differences in maternal age, "race," and marital status between children whose parents were interviewed and those whose parents were located but not interviewed.[9]

Trained interviewers conducted in-home interviews between November 1991 and April 1992. During the interview, parents were asked to name all outpatient care

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providers used by the child since birth. The parents of 546 children (98%) gave written informed consent to review their children's medical records. Two trained auditors collected vaccination dates and visit data from the medical records of 525 of the 546 children.

Data analysis. Using these medical records audits, we analyzed the coverage of the 525 children in the sample based on the indicators listed in Table 1, which are divided into those indicating age-appropriate vaccination and those indicating up-to-date vaccination. An age-appropriate vaccination is one given during the age interval recommended for that vaccine dose (we used the then-current schedule listed in the 1988 edition of the American Academy of Pediatrics' *Red Book*.[16]). In this analysis, up-to-date (UTD12 or UTD24) refers to receipt of vaccinations by the indicated age, regardless of the interval between doses For detailed definitions of age-appropriate indicators, see "Definitions of Indicators Used in Present Study," page 530, and an earlier publication.[9] We did not include Hib vaccination in the analysis because Hib was a new vaccine at the time of the survey and was available at few sites.

We also calculated the predictive value of certain indicators.[17] We calculated the value of failure to achieve each indicator as a predictor of failure to achieve up-to-date status at age 2 years for the combined DTP/OPV/ MMR series. For example, the predictive value of DTP1-AA describes what percentage of all the children in the sample who *did not* receive DTP1 age-appropriately were also *not* up-to-date for DTP/OPV/MMR by age 2 years. We phrased the predictive power in negative terms because we were primarily interested in identifying those children who failed to be vaccinated and therefore required follow-up.

Table 1. Comparison of vaccination coverage using up-to-date and equivalent age-appropriate indicators, 525 inner-city children born August 1988 through March 1989, Baltimore, Maryland

Indicator	*Coverage*
DTP-UTD12	69.9
DTP3-AA	32.8
DTP-UTD24	56.4
DTP4-AA	16.0
OPV-UTD24	63.2
OPV3-AA	21.3
MMR-UTD24	78.9
MMR1-AA	38.3
DTP4/OPV3/MMR1-UTD24	53.9
DTP4/OPV3/MMR1-AA	13.0

NOTE: DTP-UTD12 (up-to-date at age 12 months for DTP) coverage means the proportion of children who by age 12 months had received three doses of DTP, as recommended by the American Academy of Pediatrics (AAP) for this age cohort (Reference 16). OPV-UTD12 (up-to-date at age 12 months for polio) coverage means the proportion of children who by age 12 months had received two doses of polio vaccine, as recommended by the AAP for this age cohort. AA coverage represents the proportion of children who received each dose of vaccine during the age interval recommended by the AAP for that dose; for example, DTP3-AA coverage represents the proportion of children who received each of the first three doses of DTP during the recommended age intervals.

AA = age-appropriate
DTP = diphtheria vaccine, tetanus toxoid, and pertussis vaccine or diphtheria vaccine and tetanus toxoid (DT)
MMR = measles, mumps, and rubella vaccine
OPV = oral polio vaccine or inactivated polio vaccine (IPV))
UTD12 = up-to-date at 12 months of age
UTD24 = up-to-date at 24 months of age

RESULTS

Table 1 shows the vaccination status for the 525 children in the sample, according to the various indicators. In each case, the up-to-date coverage measure was at least 37 percentage points higher than the equivalent age-appropriate measure. Only 13.0% of children received the full then-recommended primary series during the recommended time intervals. Table 2 describes the ability of selected indicators to predict up-to-date status at 2 years

Table 2. Predictive value of selected vaccination indicators for children's *not* being up-to-date for DTP/OPV/MMR vaccinations by age 2 years, 525 inner-city children born August 1988 through March 1989, Baltimore, Maryland

Indicator not met	*Predictive value for failure to be up-to-date at 24 months*
DTP1-AA	79.5
DTP3-AA	58.4
DTP-UTD12	91.1
DTP4-AA	54.6
OPV1-AA	79.1
OPV3-AA	56.7
OPV-UTD12	97.6
MMR1-AA	59.6

NOTE: Predictive value refers to the likelihood that a child who had not achieved the immunization indicator in the left column had also not been vaccinated with the complete then-recommended series of four DTP, three OPV, and one MMR vaccinations by age 2 years.

AA = age-appropriate
DTP = diphtheria vaccine, tetanus toxoid, and pertussis vaccine or diphtheria vaccine and tetanus toxoid (DT)
MMR = measles, mumps, and rubella vaccine
OPV = oral polio vaccine or inactivated polio vaccine (IPV))
UTD12 = up-to-date at 12 months of age

for DTP/OPV/MMR. While not being up-to-date at 12 months of age was the best predictor of not being up-to-date at 24 months, nearly 80% of children who *did not* receive DTP1-AA or OPV1-AA were *not* up-to-date at age 2 years.

DISCUSSION

The recommended schedule of vaccinations is intended to provide the best protection against infection. Therefore, the true measure of the extent of protection of the population is the percentage who have been vaccinated according to the schedule. The vaccination schedules recommended by the American Academy of Pediatrics in 1988 and today both require children to complete the primary series at 18 months. Measuring coverage at 24 months allows children to be up to six months behind in vaccinations for polio and DTP and nine months behind for MMR and still catch up to meet the national goals. CDC has not improved this problem by expanding the NHIS to include children ages 19–35 months. With this modification, children can be up to 20 months behind for MMR and still be considered up-to-date.

We found that the relatively low UTD24 coverage levels in Baltimore masked even lower levels of children vacci-

DEFINITIONS OF INDICATORS USED IN PRESENT STUDY, BASED ON THE 1988 AMERICAN ACADEMY OF PEDIATRICIANS' RECOMMENDED INTERVALS FOR ADMINISTRATION OF CHILDHOOD VACCINATIONS

Indicator	*Definition*
DTP1-AA	First dose of DTP received between 42 and 92 days inclusive
OPV1-AA	First dose of OPV received between 42 and 92 days inclusive
DTP3-AA	Third dose of DTP received at least 28 days after second dose of DTP and on or before 213 days of life and second dose of DTP received at least 28 days after first dose
OPV3-AA	Second dose of OPV received at least 28 days after first dose of OPV and third dose of OPV received at least 28 days after second dose of OPV and between 426 and 579 days of life, inclusive, *or:* Fourth dose of OPV received at least 28 days after third dose of OPV and between 426 and 579 days of life, inclusive
DTP4-AA	Fourth dose of DTP received at least 184 days after third dose of DTP and between 426 and 579 days of life, inclusive; second dose of DTP received at least 28 days after first dose; third dose of DTP received at least 28 days after second dose
MMR-AA	A dose of MMR (either first or second dose) given between 366 and 517 days of life, inclusive

AA = age-appropriate
DTP = diphtheria vaccine, tetanus toxoid, and pertussis vaccine or diphtheria vaccine and tetanus toxoid (DT)
OPV = oral polio vaccine or inactivated polio vaccine (IPV))
MMR = measles, mumps, and rubella vaccine

SOURCE: Reference 16

"Population-based registries could provide a source from which to easily calculate age-appropriate indicators, both for the individual child and the population as a whole."

nated on time (Table 1). This finding confirms those of a 1992 nationwide study, which found that the percentages of preschool children age-appropriately vaccinated for DTP/OPV/MMR and for each individual vaccine were much lower than the percentages up-to-date at age 2 years.[18]

Based on these findings, the inclusion of up-to-date at 24 months in HEDIS[19] as a marker for quality of primary health care delivery appears to be inadequate. Given the inability of up to date at 24 months to monitor on-time delivery of vaccinations, if vaccination indicators are to be used as measures of the quality of care, then age-appropriate indicators are much more appropriate than up to date at 24 months. Age-appropriate indicators monitor the timing of contact between the child and providers and are therefore a better indicator of the quality of health care delivery. Delay in receiving vaccinations has been found to have implications for the receipt of other preventive health care measures. Rodewald et al. have found an association between time spent undervaccinated and the likelihood of not being screened for developmental disorders, anemia, elevated serum lead, and tuberculosis.[20]

The present study's finding that early age-appropriate indicators (DTP-1 and OPV-1) predict later vaccination status is corroborated by a substantial literature linking the timing of the first DTP immunization (DTP1) with later vaccination status.[21-28] Using these indicators would allow providers to focus attention early on children who are most likely to fall behind. Monitoring DTP1 would be a highly efficient and timely method of identifying children in need of special attention. The ability to identify at-risk children early on, and thus intervene early, suggests DTP1-AA is a more useful indicator than up to date at 12 months, despite the latter's higher predictive value.

We have outlined a series of important shortcomings in up-to-date indicators at both the population and individual level that could be improved by adding age-appropriate measures. Monitoring age-appropriate indicators has important methodologic implications. Assessing age-appropriate immunization requires access to the dates of all vaccinations given. This information is more accurately obtained from automated data than from parent recall.[29,30] The CDC now uses audit-based survey methods to estimate population-based vaccination coverage because of concerns about the accuracy of parental recall. As the CDC relies more heavily on audits, it is increasing its access to age-appropriate coverage information for the population. Therefore, access to data on age-appropriate measures at the population level is becoming less and less difficult. Population-based registries could provide a source from which to easily calculate age-appropriate indicators, both for the individual child and the population as a whole.

With the rise of managed care, such registries are becoming feasible for an increasing proportion of the population. Public health researchers should encourage the development of registries by promoting the benefits of age-appropriate indicators as tools to improve preventive care and reduce the burden of disease.

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