ARTICLE

# Maternal and Birth Attendant Hand Washing and Neonatal Mortality in Southern Nepal

*Victor Rhee, MHS; Luke C. Mullany, PhD; Subarna K. Khatry, MBBS; Joanne Katz, ScD; Steven C. LeClerq, MPH; Gary L. Darmstadt, MD; James M. Tielsch, PhD*

**Background:** More than 95% of neonatal deaths occur in developing countries, approximately 50% at home. Few data are available on the impact of hand-washing practices by birth attendants or caretakers on neonatal mortality.

**Objective:** To evaluate the relationship between birth attendant and maternal hand-washing practices and neonatal mortality in rural Nepal.

**Design:** Observational prospective cohort study.

**Setting:** Sarlahi District in rural southern Nepal.

**Participants:** Newborn infants were originally enrolled in a community-based trial assessing the effect of skin and/or umbilical cord cleansing with chlorhexidine on neonatal mortality in southern Nepal. A total of 23 662 newborns were enrolled and observed through 28 days of life.

**Main Exposures:** Questionnaires were administered to mothers on days 1 and 14 after delivery to identify care practices and risk factors for mortality and infection. Three hand-washing categories were defined: (1) birth attendant hand washing with soap and water before assisting with delivery, (2) maternal hand washing with soap and water or antiseptic before handling the baby, and (3) combined birth attendant and maternal hand washing.

**Outcome Measures:** Mortality within the neonatal period.

**Results:** Birth attendant hand washing was related to a statistically significant lower mortality rate among neonates (adjusted relative risk [RR] = 0.81; 95% confidence interval [CI], 0.66-0.99), as was maternal hand washing (adjusted RR = 0.56; 95% CI, 0.38-0.82). There was a 41% lower mortality rate among neonates exposed to both hand-washing practices (adjusted RR = 0.59; 95% CI, 0.37-0.94).

**Conclusions:** Birth attendant and maternal hand washing with soap and water were associated with significantly lower rates of neonatal mortality. Measures to improve or promote birth attendant and maternal hand washing could improve neonatal survival rates.

*Arch Pediatr Adolesc Med. 2008;162(7):603-608*

**Author Affiliations:** Department of International Health, Johns Hopkins Bloomberg School of Public Health, Baltimore, Maryland, (Messrs Rhee and LeClerq and Drs Mullany, Katz, Darmstadt, and Tielsch); and the Nepal Nutrition Intervention Project, Sarlahi, Kathmandu, Nepal (Dr Khatry and Mr LeClerq).

ALTHOUGH MAJOR ACHIEVEMENTS have been made in reducing mortality in children younger than 5 years, less progress has been made in reducing neonatal mortality.[1] About 4 million neonatal deaths occur each year, more than 99% in low and middle-income countries. About half of these deaths occur at home where mothers receive little or no perinatal care.[2,3] These neonatal deaths are attributable primarily to infections, prematurity, and birth asphyxia.[3]

Current evidence suggests that universal provision of low-cost interventions could reduce these rates by up to 70%.[4] These interventions include maternal tetanus toxoid immunization, clean delivery and cord care, resuscitation of newborns, early initiation of exclusive breastfeeding, prevention and management of hypothermia, skin-to-skin care, and community-based pneumonia case management. In addition, the World Health Organization has recommended hand washing with clean water and soap before and after handling the infant during the postnatal period to prevent infection.[5]

More than 150 years have elapsed since Semmelweis first demonstrated the importance of hand washing in the prevention of obstetrical nosocomial infection.[6]

Hand washing has also been shown to reduce the risk of gastrointestinal infections, pneumonia, and nosocomial infections.[7-19] A recent meta-analysis estimated that handwashing could reduce the risk of diarrhea by 42% to 44% in older preschool-aged children.[20] Despite strong evidence for reduced incidence of infection due to hand washing, few estimates are available to quantify the potential impact of hand-washing practices by birth attendants or caretakers in developing country settings on mortality and morbidity during the neonatal period. As a part of community-based trials of skin and umbilical cord cleansing with chlorhexidine and neonatal mortality and morbidity, we had the opportunity to examine the strength of the relationship between hand-washing behaviors and neonatal death.

## METHODS

The data for this secondary analysis come from a nested pair of double-masked, placebo-controlled, cluster-randomized, community-based trials conducted in the Sarlahi District of southern Nepal. These trials evaluated the effect of skin and umbilical cord cleansing with chlorhexidine on neonatal mortality and omphalitis. Descriptions of the study population, recruitment and randomization procedures, skin and cord treatment regimens, and follow-up activities have been reported previously.[21,22] In summary, pregnant women were approached for enrollment during mid-pregnancy by local female staff. Study procedures were explained and oral informed consent was obtained. All participating women received iron–folic acid supplements, a single dose of albendazole, weekly vitamin A supplementation, and a clean birthing kit consisting of a small bar of soap, a clean razor blade, string, a plastic disc, and a piece of plastic sheeting. At the time of enrollment, women were counseled on appropriate prenatal nutrition and health issues, clean and safe birthing practices including hand washing by the birth attendant before delivery and by the mother prior to handling her baby, newborn thermal control, and hygienic care of the umbilicus. This prenatal counseling session lasted approximately 30 to 40 minutes and used specially developed visual aids. Infants born alive between September 2002 and March 2005 who were alive at 1 or more home visits by workers during the postnatal period were eligible for enrollment. In March 2005, the study's Data Safety and Monitoring Board recommended that all infants receive the active interventions (single full-body skin cleansing and multiple-day cord cleansing with chlorhexidine). For this analysis, all live births occurring between the start of the trials and including the postrandomization phase (through January 2006) were included.

Enrolled newborns were visited up to 11 times on days 1 through 4, 6, 8, 10, 12, 14, 21, and 28. At each home visit, workers recorded the vital status of the child and signs of omphalitis and other morbidities, and measured axillary temperature. On the first visit and 2 weeks later, field workers administered a questionnaire to identify neonatal care practices and potential risk factors for neonatal morbidity. The questionnaire on day 1 focused on the delivery of the newborn and immediate newborn care practices, including birth attendant hand-washing practices, as well as measurement of birth weight. Birth attendant hand washing was defined as a positive response to the question "Did the person assisting with delivery wash their hands with soap and water before delivery?" Gestational age was estimated as time since the last menstrual period, based on maternal reporting during enrollment and at the day 1 visit. The questionnaire on day 14 assessed the duration and frequency of various newborn care practices since birth, including maternal hand washing prior to handling the infant. Maternal hand washing was defined as a response of "sometimes" or "always" to the question "Do you wash your hands with soap and water, antiseptic, or nim before handling the baby?" Infants who had specific sets of signs and symptoms at the time of household visits were referred to the local health system for care. Maternal hand-washing status was not assessed for infants who died prior to the first post-delivery study visit. All infants who were alive after 28 days were discharged from the study.

The primary outcome variable for this analysis was all-cause mortality from enrollment through 28 days. Binomial regression with a log link function was used to model the relative risk of death, using the hand-washing status of the birth attendant and the mother. Similar models were used to control for confounding and to explore potential interactions. Additional analyses were conducted restricting the data set to those infants who were first enrolled on days 2, 3, and 7, to determine the effect of hand-washing behavior with the exclusion of early neonatal deaths.

Statistical analyses were conducted using STATA Version 9.2 (Stata Corp Inc, College Station, Texas). This study received ethical approval from the Nepal Health Research Council and the Committee on Human Research of the Johns Hopkins Bloomberg School of Public Health, Baltimore, Maryland, and is registered at Clinicaltrials.gov (NCT00109616).

## RESULTS

A total of 23 662 live neonates were born between September 1, 2002, and January 31, 2006, who were eligible for enrollment in the study. More than 90% of births occurred at home or outdoors during transport to a facility. The median time to the first study visit was 19.3 hours and 63% were first visited within 24 hours. Fewer than 5% of eligible subjects were not enrolled for various reasons, including inability to meet the mother and newborn within the first 28 days of life, refusal, emigration, and infant death prior to the first study visit. Maternal hand-washing status was not available for infants who died prior to the first postdelivery study visit. Characteristics of the study population are presented in **Table 1**. There were slightly more male than female infants enrolled and approximately 70% were from the Madeshi ethnic group. Only about a quarter of mothers had ever attended primary school and other socioeconomic indicators classified this population as poor, even for rural Nepal. Approximately 30% of infants were low birth weight (<2500 g) and about 18% were preterm (Table 1).

The overall mortality rate among enrolled infants was 32.1 per 1000 live births. Birth attendants washed their hands prior to delivery for 59.2% of live births, whereas only 14.8% of mothers reported washing their hands with soap and water or antiseptic prior to handling their infant (**Table 2**). Neonatal mortality was significantly lower among infants whose birth attendant and/or mother washed their hands with soap and water or antiseptic. Newborns whose birth attendant washed his or her hands before assisting with delivery had a 25% lower risk of death compared with newborns whose birth attendant did not wash his or her hands (relative risk [RR] = 0.75; 95% confidence interval [CI], 0.65-0.86) (Table 2). Infants whose

mothers washed their hands prior to handling their infant had a 60% lower risk of neonatal death compared with those whose mothers did not wash their hands (RR=0.40; 95% CI, 0.28-0.59) (Table 2). These effects were not independent, as shown by the combined effect of both the birth attendant and mother washing their hands (RR=0.44; 95% CI, 0.28-0.68) (Table 2). Excluding the 271 deaths that occurred prior to the first postdelivery study visit made only modest changes to the estimates of the effects of birth attendant hand-washing behavior (Table 2).

The population attributable risk percentage for hand washing by the birth attendant assisting with delivery was 12.2% (31.9 – 28.0 / 31.9=12.2%). Among those infants who survived the first few days of life, the population attributable risk percentage related to maternal hand washing with soap and water or antiseptic prior to the handling of their neonate was 55.8% (19.9 – 8.8 / 19.9=55.8%).

Stratified analyses were conducted to evaluate the presence of confounding or effect modification. Potential confounders were identified from various maternal, infant and care-practice covariates. Some of these covariates have a recognized relationship with neonatal mortality or neonatal infection (eg, birth weight, gestational age, cord cleansing with chlorhexidine[21-23]). Binomial regression with a log link function was used to model the RR of these covariates with neonatal mortality. Similar models were created to estimate the relationship between these covariates and birth attendant and maternal hand-washing behaviors.

There was no evidence for effect modification of the relationship between hand-washing behavior and risk of mortality by sex or treatment group assignment. However, hand-washing behaviors tended to have larger effects on mortality among infants with indicators of higher underlying risk such as Madeshi ethnicity, low birth weight, preterm birth, low maternal education, and those without a latrine in the household, although the strength of evidence for interaction was only modest (**Table 3**).

Adjustment for a number of potentially confounding variables, including birth weight, gestational age, mother's age, receipt of colostrum, breastfeeding initiation time, and treatment groups, did not materially change the relationship between birth attendant hand washing and neonatal mortality (adjusted RR=0.80; 95% CI, 0.65-0.98). After adjusting for these same covariates, the magnitude of the relationship between maternal hand washing and neonatal mortality was reduced from a 60% reduction to a 44% reduction (adjusted RR=0.56; 95% CI, 0.38-0.82). Similarly, the strength of the relationship between combined birth attendant and maternal hand washing and neonatal mortality was reduced from a 56% to a 41% reduction in mortality (adjusted RR=0.59; 95% CI, 0.37-0.93).

In addition, RRs were calculated with the condition of survival of infants until days 2, 3, and 7 (**Table 4**). This was done to evaluate the impact of each hand-washing exposure after the exclusion of early deaths. It was initially hypothesized that excluding these deaths would show a greater impact of birth attendant hand washing relative to the impact of maternal hand washing, because the majority of very early neonatal deaths may be due to causes that might not be readily impacted by hand washing, such as birth asphyxia, prematurity, or congenital abnormalities. However, this was not supported by the data as there was little change in the relative risks after excluding these early deaths (Table 4). There was also no substantive change in the relative risk of death related to maternal hand washing as early deaths were excluded (Table 4).

**Table 1. Selected Characteristics by Birth Attendant Hand Washing**

| Variable | Birth Attendant Hand Washing, No. (%) Yes | No |
|---|---|---|
| Sex | | |
| Male | 6931 (52.3) | 5264 (50.6) |
| Female | 6324 (47.7) | 5143 (49.4) |
| Ethnic group[a] | | |
| Hills, Pahadi | 3898 (29.4) | 2729 (26.2) |
| Plains, Madeshi | 9143 (69.0) | 7503 (72.1) |
| Maternal education[b] | | |
| None | 9574 (72.2) | 8414 (80.9) |
| Any | 3668 (27.7) | 1984 (19.1) |
| Electricity in house[c] | | |
| No | 9533 (71.9) | 8078 (77.6) |
| Yes | 3501 (26.4) | 2161 (20.8) |
| Latrine at house[d] | | |
| None | 11 197 (84.5) | 9306 (89.4) |
| Any latrine | 1826 (13.8) | 907 (8.7) |
| Ownership | | |
| Rice paddy land[e] | 6761 (51.0) | 4958 (47.6) |
| Cattle[f] | 8084 (61.0) | 6090 (58.5) |
| Radio[g] | 4162 (31.4) | 2820 (27.1) |
| Television[h] | 2645 (20.0) | 1569 (15.1) |
| Bicycle[i] | 7146 (53.9) | 5209 (50.1) |
| Median time to first study visit, h | 18.4 | 20.5 |
| Visited within 24 h | 8817 (37.3) | 6080 (25.7) |
| Breastfed within 12 h after delivery | 5558 (41.9) | 3964 (38.1) |
| Infant given colostrum[1,j] | 10 535 (79.5) | 8090 (77.7) |
| Used clean blade to cut umbilical cord | 12 447 (93.9) | 8576 (82.4) |
| Birth weight, g[1,k] | | |
| <2500 | 3771 (28.5) | 3013 (29.0) |
| ≥2500 | 9253 (69.8) | 6724 (64.6) |
| Gestational age, wk | | |
| <37 | 2275 (17.2) | 2045 (19.7) |
| ≥37 | 10 980 (82.8) | 8362 (80.4) |
| Skin cleansing treatment | | |
| Chlorhexidine | 8451 (63.8) | 6331 (60.8) |
| Placebo | 4804 (36.2) | 4076 (39.2) |
| Cord cleansing treatment | | |
| Chlorhexidine | 6366 (48.0) | 4938 (47.5) |
| Education only | 3897 (29.4) | 3142 (30.2) |
| Soap and water | 2992 (22.6) | 2327 (22.4) |

Total missing information for each characteristic:
[a] Yes: 214 (1.6%), No: 175 (1.7%)
[b] Yes: 13 (0.1%), No: 9 (0.1%)
[c] Yes: 221 (1.7%), No: 168 (1.6%)
[d] Yes: 232 (1.8%), No: 194 (1.9%)
[e] Yes: 320 (2.4%), No: 265 (2.6%)
[f] Yes: 223 (1.7%), No: 170 (1.6%)
[g] Yes: 225 (1.7%), No: 170 (1.6%)
[h] Yes: 222 (1.7%), No: 169 (1.6%)
[i] Yes: 226 (1.7%), No: 168 (1.6%)
[j] Yes: 361 (2.7%), No: 374 (3.6%)
[k] Yes: 231 (1.7%), No: 670 (6.4%)

**Table 2. Unadjusted Relationship Between Birth Attendant and Maternal Hand-Washing Behavior and Neonatal Mortality**

| | Total | | | | Excluding Early Deaths[b] | | | |
|---|---|---|---|---|---|---|---|---|
| | Deaths | Births | Rate[a] | RR (95% CI) | Deaths | Births | Rate[a] | RR (95% CI) |
| Birth attendant hand washing | | | | | | | | |
| Yes | 371 | 13 255 | 28.0 | 0.75 (0.65-0.86) | 240 | 13 124 | 18.3 | 0.81 (0.68-0.98) |
| No | 342 | 9123 | 37.5 | 1.00 | 202 | 8982 | 22.5 | 1.00 |
| Maternal hand washing[c] | | | | | | | | |
| Yes | | | | | 30 | 3403 | 8.8 | 0.40 (0.28-0.58) |
| No | | | | | 427 | 19 592 | 21.8 | 1.00 |
| Combined hand washing[c] | | | | | | | | |
| Yes | | | | | 21 | 2267 | 9.3 | 0.44 (0.28-0.68) |
| No | | | | | 413 | 19 520 | 21.2 | 1.00 |

Abbreviations: CI, confidence interval; RR, relative risk.
[a] Rate per 1000 live births.
[b] Early deaths are defined as those occurring prior to the first data collection visit by study staff after delivery.
[c] Early deaths are excluded in the maternal hand-washing and combined hand-washing analyses.

**Table 3. Unadjusted Relationship Between Hand-Washing Behavior and Neonatal Mortality by Selected Characteristics of the Population**

| | RR (95% CI) | | |
|---|---|---|---|
| Variable | Birth Attendant Hand Washing | Maternal Hand Washing | Combined Hand Washing |
| Birth weight, g | | | |
| <2500 | 0.64 (0.50-0.82) | 0.50 (0.31-0.81) | 0.41 (0.21-0.78) |
| ≥2500 | 1.34 (0.92-1.97) | 0.56 (0.30-1.05) | 0.77 (0.40-1.48) |
| *P* value | .001 | .76 | .17 |
| Ethnic group | | | |
| Hills, Pahadi | 0.93 (0.66-1.30) | 0.60 (0.32-1.09) | 0.83 (0.44-1.57) |
| Plains, Madeshi | 0.73 (0.62-0.86) | 0.38 (0.24-0.61) | 0.33 (0.18-0.61) |
| Test for interaction | *P*=.21 | *P*=.25 | *P*=.04 |
| Gestational age, wk | | | |
| <37 | 0.67 (0.54-0.82) | 0.30 (0.15-0.62) | 0.24 (0.09-0.64) |
| ≥37 | 0.87 (0.71-1.05) | 0.52 (0.34-0.80) | 0.62 (0.38-1.01) |
| *P* value | .08 | .20 | .09 |
| Maternal education | | | |
| None | 0.76 (0.65-0.89) | 0.37 (0.23-0.59) | 0.40 (0.22-0.70) |
| Any formal education | 0.83 (0.57-1.20) | 0.56 (0.30-1.03) | 0.62 (0.31-1.24) |
| *P* value | .69 | .29 | .32 |
| Latrine at home | | | |
| No | 0.75 (0.65-0.87) | 0.36 (0.23-0.55) | 0.38 (0.23-0.64) |
| Yes | 0.88 (0.51-1.54) | 0.90 (0.41-2.00) | 0.90 (0.37-2.17) |
| *P* value | .58 | .04 | .10 |

Abbreviations: CI, confidence interval; RR, relative risk.

## COMMENT

These data provide evidence that birth attendant and maternal hand washing are related to markedly lower risk of mortality among neonates in southern Nepal after accounting for other risk factors for mortality. The adjusted risk of death was 19% lower among newborns whose birth attendants washed hands before assisting with delivery, and 44% lower among newborns whose mothers sometimes or always washed hands with soap and water or antiseptic prior to the handling of their child. The effects of birth attendant and maternal hand washing, however, were not independent. Among newborns exposed to both birth attendant and maternal hand washing, the risk of death was 41% lower.

Hand washing appears to be more beneficial among infants with characteristics that are associated with poorer outcomes, such as low socioeconomic status, low birth weight, and preterm birth. For instance, the benefit of hand washing to neonatal mortality was greater among low birth weight infants compared with normal-weight infants (Table 3). While the strength of evidence for effect modification was weak, this trend was evident for other covariates as well. Mortality due to infection likely makes up a greater proportion of deaths among infants with these characteristics. The trend seen here is consistent with the hypothesis that hand washing reduces overall exposure of the newborn to potentially invasive pathogens, and thus affects mortality due to infection.

Our results are consistent with previous data on the effect of hand washing on reduction of infectious diseases such as diarrhea and pneumonia.[9,10,19] However, most of these studies were conducted in older children and there is little information on the effect of hand washing in the neonatal period. A strength of our study is its focus on the neonatal period where it fills an important gap in our knowledge of the protection offered by hand washing in high-risk environments.

Hand-washing behavior by mothers and traditional birth attendants in this population has been a focus of educational efforts during prenatal counseling in our studies for a number of years. Given the implied social acceptability of hand washing, it may be that women who report washing their hands remain different from those who do not with regard to important characteristics related to mortality that were not measured in this study (eg, skin-to-skin care) and unadjusted for in the analysis. This residual confounding, together with our dependence on subjective reporting of hand-washing behavior, could explain part or all of the remaining protective effect observed in this report.[24,25] Given that we have adjusted for some important confounding factors and that association with higher-risk infants was even stronger,

**Table 4. Adjusted Relationship Between Birth Attendant and Maternal Hand Washing and Neonatal Mortality Beginning at Selected Times Since Delivery**

| Conditioned on Survival at Day | RR (95% CI) | | | | | |
|---|---|---|---|---|---|---|
| | Birth Attendant | | Maternal | | Combined | |
| | Unadjusted | Adjusted[a] | Unadjusted | Adjusted[a] | Unadjusted | Adjusted[a] |
| 0, total | 0.75 (0.65-0.86) | 0.81 (0.66-0.99) | 0.40 (0.28-0.58) | 0.56 (0.38-0.82) | 0.44 (0.28-0.68) | 0.59 (0.37-0.94) |
| 2 | 0.72 (0.58-0.89) | 0.72 (0.57-0.91) | 0.46 (0.30-0.69) | 0.59 (0.39-0.90) | 0.44 (0.26-0.73) | 0.55 (0.32-0.95) |
| 3 | 0.77 (0.60-0.98) | 0.78 (0.61-1.02) | 0.50 (0.32-0.79) | 0.66 (0.42-1.02) | 0.44 (0.25-0.79) | 0.58 (0.32-1.03) |
| 7 | 0.74 (0.55-1.01) | 0.75 (0.54-1.03) | 0.67 (0.41-1.08) | 0.83 (0.51-1.35) | 0.57 (0.30-1.09) | 0.70 (0.37-1.33) |

Abbreviations: CI, confidence interval; RR, relative risk.
[a] Adjusted for body wash treatment, cord cleansing treatment, birth weight, gestational age, maternal age, the receipt of colostrum, and breastfeeding initiation time.

we think it unlikely that this would compromise the findings in this study.

A significant limitation of our analysis is the forced exclusion of very early deaths in the assessment of maternal and combined maternal and birth attendant handwashing. In these latter 2 analyses, the appropriate interpretation is that maternal hand washing was related to reduced mortality among infants who survived the first few days of life.

It has been estimated that 30 000 newborns die each year in Nepal, where the neonatal mortality rate is approximately 39 deaths per 1000 live births.[26] Furthermore, the World Health Organization has estimated that 39% of deaths among neonates in Nepal are attributable to pneumonia, meningitis, sepsis/septicemia, and diarrheal disease.[27] Our data suggest that a substantial proportion of these deaths may be preventable with routine hand-washing practices. If the population attributable risk percentages of between 12% and 56% observed in our study can be applied to the 4 million annual neonatal deaths worldwide, promotion of appropriate handwashing practices in developing countries like Nepal may have a tremendous impact in reaching Millennium Development Goal 4.[28]

Birth attendant hand washing with soap and water is well accepted as the standard of care in developed countries. In developing countries, where most births take place at home, the concept of washing with soap before delivery to protect against infection is not well understood.[29] In agreement with the recommendations of Curtis and Carincross[20] for future research, new and existing approaches to hand-washing promotion need to be further evaluated. As hand-washing behaviors are notably complex, indicators are also needed to evaluate and validate the compliance of hand-washing promotion when moved from research to programs and policy.

**Accepted for Publication:** November 15, 2007.
**Correspondence:** James M. Tielsch, PhD, Department of International Health, Johns Hopkins Bloomberg School of Public Health, 615 N Wolfe St, Room W5009, Baltimore, MD 21205-2103 (jtielsch@jhsph.edu).
**Author Contributions:** Dr Tielsch had full access to all of the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis. *Study concept and design:* Mullany, Katz, LeClerq, Darmstadt, and Tielsch. *Acquisition of data:* Mullany, Khatry, Katz, LeClerq, and Tielsch. *Analysis and interpretation of data*: Rhee, Mullany, Katz, Darmstadt, and Tielsch. *Drafting of the manuscript*: Rhee, Katz, Darmstadt, and Tielsch. *Critical revision of the manuscript for important intellectual content:* Rhee, Mullany, Khatry, Katz, LeClerq, Darmstadt, and Tielsch. *Statistical analysis:* Rhee, Mullany, and Katz. *Obtained funding:* Darmstadt and Tielsch. *Administrative, technical, or material support:* Khatry, LeClerq, Darmstadt, and Tielsch. *Study supervision:* Mullany, Khatry, Katz, LeClerq, and Tielsch.
**Role of the Sponsors:** The above-mentioned funding agencies had no role in the design and conduct of the study, the collection, management, analysis, and interpretation of the data, or in preparation, review, or approval of the manuscript.
**Financial Disclosure:** None reported.
**Previous Presentations:** These data were presented previously at the Pediatric Academic Societies Meeting, Toronto, Canada, May 2007.
**Funding/Support:** This study was conducted by the Department of International Health, Bloomberg School of Public Health, Johns Hopkins University, Baltimore, Maryland, under grants from the National Institutes of Health, Bethesda, Maryland (HD 44004, HD 38753), the Bill and Melinda Gates Foundation, Seattle, Washington (810-2054), and Cooperative Agreements between Johns Hopkins University and the Office of Health and Nutrition, US Agency for International Development, Washington, DC (HRN-A-00-97-00015-00, GHS-A-00-03-000019-00). Commodity support was provided by Procter and Gamble Company, Cincinnati, Ohio.

## REFERENCES

1. Lawn JE, Cousens S, Darmstadt GL, Paul V, Martines J. Why are 4 million newborn babies dying every year? *Lancet.* 2004;364(9450):2020.
2. Zupan J, Aahman E. *Perinatal Mortality for the year 2000: Estimates Developed by the WHO.* Geneva, Switzerland: World Health Organization; 2005.
3. Lawn JE, Cousens S, Zupan J. 4 million neonatal deaths: when? where? why? *Lancet.* 2005;365(9462):891-900.
4. Darmstadt GL, Bhutta ZA, Cousens S, Adam T, Walker N, de Bernis L. Evidence-based, cost-effective interventions: how many newborn babies can we save? *Lancet.* 2005;365(9463):977-988.
5. World Health Organization. *Care of the Umbilical Cord: A Review of the Evidence.* Geneva, Switzerland: World Health Organization; 1998.
6. Semmelweis IP. *Die Aetiologie der Begriff und die Prophylaxis des Kindbettfiebers.* Pest, Hungary: C.A. Hartleben's Verlags-Expedition; 1861:1543.

7. Khan MU. Interruption of shigellosis by handwashing. *Trans R Soc Trop Med Hyg*. 1982;76(2):164-168.
8. Black RE, Dykes A, Andersons K, et al. Handwashing to prevent diarrhea in day-care centers. *Am J Epidemiol*. 1981;113(4):445-451.
9. Shahid NS, Greenough WB, Huq MI, Rahman N. Hand washing with soap reduces diarrhoea and spread of bacterial pathogens in a Bangladesh village. *J Diarrhoeal Dis Res*. 1996;14(2):85-89.
10. Luby SP, Agboatwalla M, Painter J, et al. Combining drinking water treatment and hand washing for diarrhoea prevention, a cluster randomised controlled trial. *Trop Med Int Health*. 2006;11(4):479-489.
11. Luby SP, Agboatwalla M, Feikin DR, et al. Effect of handwashing on child health: a randomised controlled trial. *Lancet*. 2005;366(9481):225-233.
12. Roberts L, Jorm L, Patel M, Smith W, Douglas R, McGilchrist C. Effect of infection control measures on the frequency of diarrheal episodes in child care: a randomized, controlled trial. *Pediatrics*. 2000;105(4 Pt 1):743-746.
13. Barros AJ, Ross D, Fonseca W, Williams L, Moreira-Filho D. Preventing acute respiratory infections and diarrhoea in child day care centres. *Acta Paediatr*. 1999;88(10):1113-1118.
14. Gorter AC, Sandiford P, Pauw J, et al. Hygiene behaviour in rural Nicaragua in relation to diarrhoea. *Int J Epidemiol*. 1998;27(6):1090-1100.
15. Velema JP, van-Wijnen G, Bult P, van-Naerssen T, Jota S. Typhoid fever in Ujung Pandang, Indonesia: high-risk groups and high-risk behaviours. *Trop Med Int Health*. 1997;2(11):1088-1094.
16. Gasem MH, Dolmans W, Keuter M, Djokomoeljanto R. Poor food hygiene and housing risk factors for typhoid fever in Semarang, Indonesia. *Trop Med Int Health*. 2001;6(6):484-490.
17. Roberts L, Jorm L, Patel M, Smith W, Douglas R, McGilchrist C. Effect of infection control measures on the frequency of upper respiratory infection in child care: a randomized, controlled trial. *Pediatrics*. 2000;105(4 Pt 1):738-742.
18. Won SP, Chou HS, Hsieh WS, et al. Handwashing program for the prevention of nosocomial infections in a neonatal intensive care unit. *Infect Control Hosp Epidemiol*. 2004;25(9):742-746.
19. Peterson EA, Roberts L, Toole MJ, Peterson DE. The effect of soap distribution on diarrhea: Nyaminthuthu Refugee Camp. *Int J Epidemiol*. 1998;27(3):520-524.
20. Curtis V, Cairncross S. Effect of washing hands with soap on diarrhoea risk in the community: a systematic review. *Lancet Infect Dis*. 2003;3(5):275-281.
21. Mullany LC, Darmstadt GL, Khatry SK, et al. Topical applications of chlorhexidine to the umbilical cord for prevention of omphalitis and neonatal mortality in southern Nepal: a community-based, cluster-randomised trial. *Lancet*. 2006;367(9514):910-918.
22. Tielsch JM, Darmstadt GL, Mullany LC, et al. Impact of newborn skin-cleansing with chlorhexidine on neonatal mortality in southern Nepal: a community-based, cluster-randomized trial. *Pediatrics*. 2007;119(2):e330-e340.
23. Mullany LC, Darmstadt GL, Khatry SK, et al. Risk factors for umbilical cord infection among newborns of southern Nepal. *Am J Epidemiol*. 2007;165(2):203-211.
24. Manun'Ebo M, Cousens S, Haggerty P, Kalengaie M, Ashworth A, Kirkwood B. Measuring hygiene practices: a comparison of questionnaires with direct observations in rural Zaire. *Trop Med Int Health*. 1997;2(11):1015-1021.
25. Curtis V, Cousens S, Mertens T, Traore E, Kanki B, Diallo I. Structured observations of hygiene behaviours in Burkina Faso: validity, variability, and utility. *Bull World Health Organ*. 1993;71(1):23-32.
26. Ministry of Health and Population - Nepal, New ERA, Macro International, Inc. *Nepal Demographic and Health Survey*. Kathmandu, Nepal: Ministry of Health and Population, New ERA, and Macro International, Inc; 2006.
27. World Health Organization. *Mortality Country Fact Sheet 2006 (Nepal)*. Geneva, Switzerland: World Health Organization; 2006.
28. Department of Economic and Social Affairs. *United Nations Secretariat. The Millennium Development Goals Report 2007*. New York, NY: United Nations; 2007.
29. Darmstadt GL, Syed U, Patel Z, Kabir N. Review of domiciliary newborn care practices in Bangladesh. *J Health Popul Nutr*. 2006;24(4):380-393.