EFFECTS OF DESIGN ASSUMPTIONS ON SUDAAN VARIANCES FOR ESTIMATES OF AGGREGATES IN THE NATIONAL HOSPITAL AMBULATORY CARE SURVEY

Joe Fred Gonzalez, Jr. and Iris M. Shimizu, National Center for Health Statistics
Joe Fred Gonzalez, Jr. National Center for Health Statistics, 6525 Belcrest Rd., Room 915, Hyattsville, MD 20782

Keywords: Complex sample design; sampling error; establishment survey

1. Introduction [1]

The National Center for Health Statistics conducts the National Hospital Medical Care Survey (NHAMCS) to produce statistics about visits to emergency rooms and outpatient departments. Because the NHAMCS uses a complex multi-stage sample of visits (stratified four-stage sample design), one must use techniques such as replication or linearized Taylor series to compute variances. These variance computation methods require design information that could reveal the identities of respondents (in the case of NHAMCS the responding hospitals). In this paper, we use 1997 data to explore the effects on NHAMCS variances when design assumptions are altered in ways that would not pose confidentiality and privacy risks in NHAMCS public use files.

The next section describes the NHAMCS sampling and estimation designs and the usual procedures used to approximate the variances of estimates. Section 3 discusses the methodologies used to evaluate effects of alternate design assumptions on the variances. Sections 4 and 5 present the results and conclusions, respectively.

2. Design

2.1 Sample

The NHAMCS universe consists of visits to hospitals that are non-Federal, non-institutional short stay hospitals (average length of inpatient stay is less than 30 days) or general medical or general surgical hospitals (without regard to length of stay) which have at least six beds set up and staffed for inpatient care. The sampling frame consists of hospitals in SMG's 1991 Hospital Market Database (SMG 1991) which satisfied the criteria for being in the universe. The first stage sample consists of 112 primary sampling units (PSUs) which is a probability subsample of the PSUs selected for the 1985-94 National Health Interview Survey. The PSUs are counties (or county equivalents) or groups of counties except in New England where some PSUs are formed from townships. The PSUs are stratified by region, socioeconomic, and demographic characteristics and one PSU is selected from each stratum. The second stage consists of 600 hospitals that are divided into 16 national sample panels which were randomly assigned to 4-week reporting periods. Each year data collection is attempted in the 13 reporting periods falling within that year. The 1997 NHAMCS included 486 hospitals of which 410 had EDs and 269 had OPDs.

For the third stage, an interviewer obtains a list of all emergency service areas (ESAs) and outpatient clinics in the hospital during a visit to the sample hospital. For each OPD clinic, the interviewer also collects specialty and the number of visits expected during the hospital's assigned reporting period. If a sample hospital has five or fewer clinic sampling units, then all are included in the sample. If a sample hospital has more than five clinics, then five units are randomly selected. For clinic selection, individual clinics are arrayed by six specialty groups: general medicine, surgery, pediatrics, obstetrics/gynecology, substance abuse, and other. Within each clinic group, clinics which expect fewer than 30 visits during the reporting period are combined to form units with a minimum of 30 visits. Five of these units are then selected with probability proportional to the number of expected visits. The 1997 NHAMCS sample included 918 clinics from 236 participating OPDs.

The emergency department was sampled as a separate stratum within each hospital. All emergency areas (ESAs) are selected with certainty except in the rare cases where an ED has more than five ESAs. In those cases, a sample of five ESAs is selected with probability proportional to the expected number of visits to the ESA. In 1997, the NHAMCS sample included 477 ESAs from 395 participating EDs.

The fourth stage sample consists of patient visits in which medical care was received. Visits made solely for paying bills or delivering specimens or visits in which no medical services are provided were not eligible. In 1997, NHAMCS included completed forms for 30,107 visits from 873 participating OPD clinics and for 22,209 visits from 475 participating ESAs. Table 1 summarizes this information.

2.2 Estimation

Statistics from the NHAMCS are derived by a multistage estimation procedure that produces essentially unbiased estimates. The estimation procedure has three

[1] The opinions expressed in this paper are those of the authors and not necessarily those of the National Center for Health Statistics.

basic components: (a) inflation by reciprocals of the sampling selection probabilities, (b) adjustment for nonresponse, and (c) a ratio adjustment.

2.2.1. Inflation by reciprocals of selection probabilities

There is one probability for each sampling stage: (a) the probability of selecting the PSU, (b) the probability of selecting the hospital, and (c) the probability of selecting the ESA or OPD clinic from within the hospital, and (d) the probability of selecting the visit within the ESA or clinic. The last probability is calculated as the sample size from the ESA or clinic divided by the product of 13 times the total number of visits occurring in that unit during the hospital's data collection period. The overall probability of selection is the product of the probabilities at each stage. The inverse of the overall selection probability is the basic inflation weight. Beginning with the 1997 data, the overall sampling weights of some OPDs were permanently trimmed to prevent individual OPDs from contributing too much of their region's total to OPD visit estimates.

2.2.2. Adjustment for nonresponse

NHAMCS data are adjusted to account for two types of nonresponse. The first type of nonresponse occurs when a sample hospital refuses to provide information about their EDs and/or OPDs which are publically known to exist. In this case, the weights of visits to hospitals similar to the nonrespondent hospitals are inflated to account for visits represented by the nonrespondent hospitals where hospitals are judged to be similar if they are in the same region, ownership control group (government, non-Federal; voluntary nonprofit; or proprietary), and have the same metropolitan statistical area (MSA) status (in an MSA versus not in an MSA). This adjustment is made separately by department type.

The second type of nonresponse occurs when a sample ESA or OPD clinic within a "respondent" hospital fails to provide completed patient record forms for a sample of their patient visits. The weights of visits to ESAs/OPD clinics similar to the nonrespondent ESAs/OPD clinics are inflated to account for visits represented by the nonrespondent ESAs/OPD clinics where ESAs/OPD clinics are judged to be similar if they are in the same region, ownership control group, MSA status group and ESA/OPD clinic group. For this purpose, there were six OPD clinic groups: general medicine, pediatrics, surgery, OB/GYN, alcohol and/or substance abuse, and other speciality.

2.2.3. Ratio adjustments

Adjustments are made within hospital strata defined by region, and within the South and West, the adjustment strata for EDs were further defined by hospital ownership control groups. These adjustments are made separately for emergency and outpatient departments. For EDs, the adjustment is a multiplicative factor that has as its numerator the sum of annual visit volumes reported for EDs in sampling frame hospitals in the stratum and as its denominator the estimated number of those visits for that stratum based on the sample hospitals. The data for the numerator and denominator of the 1997 ED adjustment is based on figures recorded in the April 1998 SMG Hospital Market Data Base file.

For OPD estimates, the ratio adjustment was replaced, beginning with the 1997 data. The original ratio used data recorded in the SMG files and it had as its numerator the number of OPDs reported in sampling frame hospitals in the stratum and as its denominator the estimated number of those OPDs for that stratum based on the sample. The new ratio adjustment uses data collected from the sample. The new ratio for the OPD estimates has as its numerator the weighted OPD visit volumes of hospitals in the full NHAMCS sample (16 hospital panels) and as its denominator the weighted OPD visit volumes of hospitals in the 13 hospital panels included in the annual sample. This adjustment uses visit volumes that are based on the most recent survey data collected from hospitals that have participated in NHAMCS for at least one year. For hospitals which have never participated, visit volumes were obtained by phone, from SMG data, or by using the average of OPD visit volumes for refusal hospitals which had converted to respondent status in the 1998 survey.

2.3. Variances

To compute the standard errors for NHAMCS statistics, NCHS uses the linearized Taylor Series approximation applied in the SUDAAN software (Shah 1997). SUDAAN's option DESIGN = WOR is typically used to compute the variances because the NHAMCS sample is selected without replacement but does not satisfy the assumptions required for using the DESIGN = UNEQWOR option.

Because only one PSU was selected from each PSU stratum, the noncertainty PSU strata are collapsed to permit the computation of PSU variances.

To simplify variance computations since NHAMCS's inception, the non-ratio adjusted weights have been used with SUDAAN to approximate variances. Theoretically, those approximations are conservative when the ratio adjustments are based upon data that is external to the sample (a condition satisfied by the SMG data) if the ratio denominators are correlated with the variables of interest. The ratio adjustments use hospital data and weights instead of visit weights. Because

SUDAAN does not accommodate the simultaneous use of two weights (both visit and hospital weights) in a single run, SUDAAN requires multiple runs to produce "exact" variances for NHAMCS's ratio-adjusted statistics.

For the 1997 OPD data, the published variances were approximated by using the final weight (ratio adjusted) in SUDAAN because the new ratio applied to the OPD estimates is based on survey sample data rather than data that is external to the sample.

3. Methodology

This investigation was conducted with the in-house variance file for the 1997 NHAMCS which contains the design variables required to correctly calculate variances for the NHAMCS estimates. SUDAAN was used to compute variances for the NHAMCS aggregate estimates assuming the original sampling design and altered design assumptions. The individual alternatives are designed to (1) reduce the resources required to approximate variances, (2) to eliminate the use of confidential total counts (for ESAs and OPD clinics within individual hospitals, and visits to individual ESAs and OPD clinics) which are required when one uses SUDAAN's DESIGN = WOR option, or (3) to explore the effect on variance approximations due to use of ratio adjusted weights in SUDAAN.

For comparison purposes in the following discussion, the variances derived under the original sampling design will be referred to as the "base standard" because it has been used since the inception of the survey and because the values of the true variances are unknown. However, for ED statistics, the variance approximations produced under the original design theoretically overstate the true variances. (The same cannot be said for the 1997 OPD statistics.) Hence, when an approximation for an ED variance from one of the alternative designs exceeds the corresponding approximation from the original design, it will also be conservative, in theory. It is deemed better to overstate, than to understate, the true variances because overstatement minimizes the possibility that someone will declare a statement to be significant when no significance would be found if the hypothesis testing were based on the true variances.

In this paper three alternative design assumptions for Ed statistics and two for OPD statistics, respectively, are investigated. These scenarios are:

For ED statistics,

1. Use the final (ratio-adjusted) weight instead of the preliminary (or non-ratio adjusted) weight in variance computations.
2. Assume visits were sampled with replacement (WR) [instead of without replacement (WOR)] and preliminary weight.
3. Assume sampling of service areas with replacement and no sampling of visits (instead of sampling both service areas and visits without replacement) and preliminary weight.

For OPD statistics

4. Use the final (ratio-adjusted) weight instead of the preliminary (or non-ratio adjusted) weight in variance computations.
5. Assume visits were sampled with replacement (WR) [instead of without replacement (WOR)] and preliminary weight.

Note that, except for scenarios 1 and 4, the variances under the alternate design assumptions are calculated with the use of the preliminary weights, as are the base standard variances. Standard errors from these scenarios were compared with those from the base standard scenario which may be comparably described as:

Base standard scenario:

Use the preliminary (non-ratio adjusted) weight in variance computations and assume sampling without replacement (WOR) at the third and fourth stages (that is for service areas/clinics and for visits). These are the design assumptions used for all variance approximations for NHAMCS until 1997.

To measure the effect (increase or decrease) on variances caused by altering the design assumptions, ratios were computed in which the numerators are the standard errors derived under the altered design assumptions and the denominators are the corresponding standard errors derived under the original sampling design. That is, the comparison ratios may be written as:

$$SERATIO = \frac{SE(NEW)}{SE(OLD)}$$

where SE(NEW) is the standard error computed while assuming one of the altered designs and SE(OLD) is the standard error computed while assuming the original design. These ratios were derived for about 7,700 ED visit statistics and about 10,400 OPD visit statistics. The statistics included in this study consist of those in cross tabulations from which statistics are taken for publication in NCHS's AdvanceData reports for NHAMCS data. Duplicate estimates (in particular most marginal estimates) and estimates based on fewer than 30 observations were deleted before the ratios were analyzed. These ratios seemed natural for this investigation because a ratio value that is less than one

means that the new or altered design variance understates the base standard variances. On the other hand, a ratio that is greater than one means that the altered design variance overstates the variance.

4. Results

The results of this investigation are shown in Tables 2-5 for the assumed alternative design scenarios described in the preceding section. These tables show summary measures for the distribution of the SERATIOs computed for the corresponding scenarios. In particular each table presents the minimum value, the 10^{th} percentile, the median, the mean, the 90^{th} percentile, and the maximum value of SERATIOs for the assumed design alternative scenario.

Table 2 shows that when the final weight instead of the preliminary weight is used to calculate the variances of ED visit statistics, over half of the SERATIOs are greater than one while 80 percent of the SERATIOs fall between 0.96 and 1.07. In other words, over half of the ED visit standard errors resulting from use of the final (ratio-adjusted) weights are more conservative (larger) than the corresponding "base standard" standard error, and more than 80 percent of the remaining standard errors are within about five percentage points of the base standard values. About 10 percent of the standard errors based on final weights are less than 96 percent (SERATIOS = 0.807 to 0.958) of the base standard errors and could lead to unjustified statements of significance. That is, for 10 percent of ED statistics, differences that are significant at the 5 percent level when tested with the new standard errors calculated with the final (instead of preliminary) weight would only be significant at the 6.4 to 11.4 percent levels when tested with the base standard errors.

Table 2 shows the effects of assuming that visits are selected with replacement at the fourth sampling stage (scenarios 2 and 5 described in the prior section). It can be seen that the SERATIOs are identically equal to one, at least to the third decimal. This could be expected because the population of visits is large relative to the number of sampled visits within each ESA and OPD clinic. Table 3 includes only the summary of SERATIOs for ED statistics because we ceased calculating the SERATIOs for OPDs statistics after we confirmed that the SERATIOs were also identically 1 for the estimates in five out of 18 groups of OPD variables. It was decided to stop calculations to conserve resources when it appeared that the SERATIO results would not differ for the remaining OPD statistics.

Table 4 shows the effects of assuming that ESAs are sampled with replacement within EDs (at the third sampling stage) and visits are NOT sampled at the fourth stage. As shown in the table, there is little variation in the SERATIOs. Their values range only from 0.989 to 1.003 and more than 80 percent of them are equal to one. This could be expected in EDs because ESAs are rarely sampled. That is, ESAs are sampled only if the ED has six or more ESAs and few EDs in the NHAMCS sample hospitals have that many ESAs.

Table 5 presents the effects of using the final weight instead of the preliminary weight to calculate the standard errors of OPD visit estimates. According to Table 5, over half of the SERATIOs for this scenario are less than one, which means that the standard errors calculated with the final weight understate the base standard errors more often than not for OPD visit statistics. More than 10 percent of the standard errors calculated under this altered design assumption are less than 95 percent (SERATIOs = 0.77 to 0.95) of the corresponding base standard errors. For OPD statistics with SERATIOs between 0.77 and .95, results for significance levels of 5 percent based on standard errors calculated with the final weight would equate to results for significance levels ranging from 6.4 to 13.4 percent based on the base standard errors (calculated with preliminary weights).

5. Conclusions

In this study, standard errors for NHAMCS aggregate visit statistics are calculated under alternative design assumptions and the effects on the standard errors due to those alternatives are examined. The "base" standards for this study are the standard errors calculated under the design assumptions that have been used to approximate the NHAMCS standard errors since the survey's inception. Specifically, the base standard errors were calculated by using the preliminary non-ratio adjusted weights and assuming sampling without replacement at all four sampling stages.

Based on study results, it appears that most of the standard errors calculated with the final (ratio-adjusted) weights were acceptable; that is, they were larger than the corresponding base standard errors or were within 5 percentage points of the corresponding base standard errors. However, for 10 percent or more of both ED and OPD statistics, the use of final weights to calculate standard errors yielded results that ranged in value from only 77 percent to 95 percent of the base standards. Such reduction in a variance approximation could change statements about statistical significance. For example, if a result is significant at the 5 percent level when one uses the base standard errors, one would have to test at the 1 percent level to get the same result when using the standard errors calculated with the final weights if those alternate errors are only 80 percent of the base standard errors.

For ED statistics, assumptions of sampling ESAs and visits with replacement (instead of without replacement) at the third and fourth stages, respectively, had no effect on the variances. This confirms that population counts of ESAs within EDs and visits within ESAs are not required for variance calculations.

Future research will include examining the effect of additional design alternatives. In particular, the effects on standard errors will be examined for the following alternatives:

a) assume sampling of OPD clinics with replacement and no sampling of visits;

b) assume sampling of both OPD clinics and visits with replacement.

References

Shah, BV; Barnwell, Bieler, GS (1997) SUDAAN User's Manual, Release 7.5. Research Triangle Park, North Carolina; Research Triangle Institute.

SMG Marketing Group Inc. (1991). 1991 Hospital Market Data Base. 1342 N. LaSalle Drive, Chicago, Illinois, 60610. SMG Marketing Group Inc.

SMG Marketing Group Inc. (1998). Hospital Market Database, April 1998 Release. John Hancock Center, Chicago, Illinois, 60611. SMG Marketing Group Inc.

Table 1: Number of departments, emergency service areas (ESAs) and outpatient clinics sampled and responding in the 1997 NHAMCS sample.

Department	Departments		ESA/Clinic	
	Sampled	Responding	Sampled	Responding
EDs	410	395	477	475
OPDs	269	236	918	873

Table 2. Percentile distribution and mean of SERATIOs for alternative design assumption 1: Use of the final weight to calculate standard errors for 1997 NHAMCS ED statistics

Statistics	Minimum	10th percentile	Median	Mean	90th percentile	Maximum	Number of Statistics
ED visits	0.807	0.958	1.006	1.011	1.067	1.501	7,690

Table 3. Percentile distribution and mean of SERATIOs for the alternative design assumptions 2 and 5: Visits are sampled with replacement to calculate standard errors for 1997 NHAMCS statistics

Statistics	Minimum	10th percentile	Median	Mean	90th percentile	Maximum	Number of Statistics
ED visits	1.000	1.000	1.000	1.000	1.000	1.000	7,690

Table 4. Percentile distribution and mean of SERATIOs for the alternative design assumption 3: Emergency services areas are sampled with replacement and visits are not sampled to calculate standard errors for 1997 NHAMCS ED statistics

Statistics	Minimum	10th percentile	Median	Mean	90th percentile	Maximum	Number of Statistics
ED visits	0.989	1.000	1.000	1.000	1.000	1.003	7,690

Table 5. Percentile distribution and mean of SERATIOs for the alternative design assumption 4: Use of the final weights to calculate standard errors for 1997 NHAMCS OPD statistics

Statistics	Minimum	10th percentile	Median	Mean	90th percentile	Maximum	Number of Statistics
OPD visits	0.767	0.935	0.979	0.984	1.028	1.433	10,398