

The prevalence and incidence of end-stage renal disease in Native American adults on the Navajo reservation

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Whereas members of the Navajo Nation are at high risk for diabetes mellitus, there are no recent published estimates of the burden of end-stage renal disease (ESRD), an important sequela of diabetes, on the Navajo Nation, a 16 million acre area in Arizona, New Mexico, and Utah with more than 200 000 tribal members. We used data from the US Renal Data System to estimate the prevalence and incidence of ESRD among Native American adults (≥ 18 years) living on the Navajo Nation. For comparison, we estimated the prevalence and incidence of ESRD among all adults in the US, all Native American adults in the US, and Native American adults living in Arizona, New Mexico, Utah, and Colorado excluding those living on the Navajo Nation. The age-adjusted prevalence of ESRD in the Native American adults on the Navajo Nation was 0.63%, which was higher than in the US adults (0.19%, $P < 0.0001$) and among the Native American adults in the US (0.36%, $P < 0.0001$), but lower than among the other Native American adults in the Southwest (0.89%, $P < 0.0001$). The age-adjusted incidence of ESRD in the Native American adults on the Navajo Nation was 0.11%, which was also higher than in the US adults (0.045%, $P < 0.0001$) and among the Native American adults in the US (0.073%, $P < 0.0009$), but lower than among the other Native American adults in the Southwest (0.17%, $P < 0.0003$). The reasons behind these disparities merit further study.

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Previous research has demonstrated considerable health disparities between members of the Navajo Nation and the general US population.^{1–3} For example, it is well established that the rates of diabetes mellitus type II are greatly elevated among the Navajo.^{4–6} In this study, we estimate the prevalence and incidence of end-stage renal disease (ESRD), an important sequela of diabetes, on the Navajo Nation.

Studies have shown that the rates of ESRD are elevated among Native Americans in the US, particularly those living in the Southwest. The age-adjusted prevalence of ESRD among Native Americans in the US is almost twice that of the general US population, whereas the age-adjusted incidence among Native Americans in the US is one and a half times that in the general US population.⁷ The age-adjusted incidence of ESRD associated with diabetes among Southwest Native Americans is almost six times that in the general US population.^{7,8}

Researchers have also looked at the rates of kidney disease among the Zuni and Pima American Indian communities, which neighbor the Navajo Nation. The age- and gender-adjusted prevalence of ESRD among Zuni adults and children, who live predominantly on the Zuni Pueblo in southern New Mexico, is 1.7%, almost nine times that in the general US population.^{9,10} Pima Indians, who live predominantly on the Gila River and Salt River Pima-Maricopa Indian Communities in Arizona, also are known to have greatly increased rates of kidney disease relative to the general US population.^{11,12}

One study from 1971 to 1985 found that the crude prevalence of ESRD among the Navajo was three times that among Caucasians in the US, whereas the crude incidence was twice that among Caucasians.¹³ These authors calculated a crude prevalence among Navajos of 0.070% and a crude incidence of 0.018% in 1985. We were unable to find any more recent studies of the burden of ESRD among Navajos. Therefore, we sought to estimate the prevalence and incidence of ESRD in this high-risk population. We hypothesized that the prevalence and incidence of ESRD among Native Americans living on the Navajo Nation would be elevated relative to those in the general US population and

the entire Native American population in the US but similar to those among other Native Americans of the Southwest.

RESULTS

The age-adjusted prevalence of ESRD in Native American adults on the Navajo Nation was approximately 3.2-fold higher than in the general US adult population ($P < 0.0001$) and 1.8-fold higher than among Native American adults in the US ($P < 0.0001$), but 29% lower than among other Native American adults living in the Southwest ($P < 0.0001$) (see Table 1). The age-adjusted prevalence of ESRD on the Navajo Nation associated with diabetes was approximately 6.2-fold higher than in the general US population ($P < 0.0001$) and 1.7-fold higher than among Native Americans in the US ($P < 0.0001$), but 41% lower than among other Native Americans living in the Southwest ($P < 0.0001$). The age-adjusted prevalence of ESRD not associated with diabetes on the Navajo Nation was approximately 1.8-fold higher than in both the general US population and among Native Americans in the US ($P < 0.0001$), and 1.3-fold higher than among other Native Americans living in the Southwest ($P < 0.006$).

The age-adjusted incidence of ESRD in Native American adults on the Navajo Nation was approximately 2.4-fold higher than in the general US population ($P < 0.0001$) and 1.5-fold higher than among Native American adults in the US ($P < 0.0009$), but 35% lower than among other Native

American adults living in the Southwest ($P < 0.0003$) (see Table 2). The age-adjusted incidence of ESRD on the Navajo Nation associated with diabetes was approximately 4.5-fold higher than in the general US population ($P < 0.0001$) and 1.6-fold higher than among Native Americans in the US ($P < 0.0005$), but 36% lower than among other Native Americans living in the Southwest ($P < 0.0004$). The age-adjusted incidence of ESRD on the Navajo Nation not associated with diabetes was not significantly different from that in the general US population (0.019 vs 0.025%, $P < 0.20$), among Native Americans in the US (0.019 vs 0.018%, $P < 0.75$), or among other Native Americans living in the Southwest (0.019 vs 0.025%, $P < 0.33$).

Table 3 shows the incidence of ESRD stratified by age. ESRD rates among adults under 45 years of age on the Navajo Nation were elevated compared with adults under 45 years of age in the general US population (0.018 vs 0.012%, $P < 0.19$), but this difference did not reach statistical significance. The rates were significantly elevated in adults 45 years and older compared with adults 45 years and older in the general US population (0.20 vs 0.081%, $P < 0.0001$), and this difference was more pronounced than that in adults under 45. ESRD rates among adults under 45 years of age on the Navajo Nation were not significantly different from those in Native American adults in the US under age 45 (0.018 vs 0.017%, $P < 0.83$); however, the rates were significantly elevated in

Table 1 | 2001 crude and age-adjusted prevalence of ESRD among four groups ≥ 18 years of age: Native Americans on the Navajo Nation, the General US Population, Native Americans in the US, and Native Americans in the Southwest excluding those on the Navajo Nation

Population	Number of persons with ESRD	Number of adults ≥ 18	Prevalence of ESRD, age adjusted (crude)	Prevalence of ESRD associated with diabetes, age adjusted (crude)	Prevalence of ESRD not associated with diabetes, age adjusted (crude)	Prevalence of ESRD in dialysis patients only, age adjusted (crude)
Native Americans on the Navajo Nation	636	130 907	0.63% (0.49%)	0.43% (0.31%)	0.21% (0.17%)	0.54% (0.41%)
General US population	400 605	212 673 000	0.19% (0.19%)	0.069% (0.069%)	0.12% (0.12%)	0.14% (0.14%)
All Native Americans in the US	5556	2 023 000	0.36% (0.27%)	0.24% (0.17%)	0.12% (0.10%)	0.29% (0.21%)
Native Americans living in AZ, NM, CO, and UT (excluding those on the Navajo Nation)	1481	250 820	0.89% (0.59%)	0.73% (0.46%)	0.16% (0.13%)	0.79% (0.52%)

ESRD, end-stage renal disease.

Table 2 | 2001 crude and age-adjusted incidence of ESRD among four groups ≥ 18 years of age: Native Americans on the Navajo Nation, the General US Population, Native Americans in the US, and Native Americans in the Southwest excluding those on the Navajo Nation

Population	Number of new cases of ESRD	Number of adults ≥ 18	Incidence of ESRD, age adjusted (crude)	Incidence of ESRD associated with diabetes, age adjusted (crude)	Incidence of ESRD not associated with diabetes, age adjusted (crude)	Incidence of ESRD in dialysis patients only, age adjusted (crude)
Native Americans on the Navajo Nation	109	130 907	0.11% (0.083%)	0.090% (0.066%)	0.019% (0.018%)	0.11% (0.083%)
General US population	93 886	212 673 000	0.045% (0.44%)	0.020% (0.020%)	0.025% (0.024%)	0.044% (0.043%)
All Native Americans in the US	1108	2 023 000	0.073% (0.055%)	0.055% (0.041%)	0.018% (0.014%)	0.072% (0.054%)
Native Americans Living in AZ, NM, CO, and UT (excluding those on the Navajo Nation)	283	250 820	0.17% (0.11%)	0.14% (0.092%)	0.025% (0.021%)	0.16% (0.11%)

ESRD, end-stage renal disease.

Table 3 | 2001 age-stratified incidence of ESRD among four groups ≥ 18 years of age: Native Americans on the Navajo Nation, the General US Population, Native Americans in the US, and Native Americans in the Southwest excluding those on the Navajo Nation

Population	18–24 (%)	25–34 (%)	35–44 (%)	45–64 (%)	≥ 65 (%)
Native Americans on the Navajo Nation	0.0074	0.017	0.028	0.15	0.31
General US population	0.0047	0.010	0.018	0.052	0.13
All Native Americans in the US	0.0049	0.014	0.029	0.097	0.20
Native Americans Living in AZ, NM, CO, and UT (excluding those on the Navajo Nation)	0.015	0.040	0.066	0.23	0.43

ESRD, end-stage renal disease.

adults 45 years and older (0.20 vs 0.12%, $P < 0.0002$). ESRD rates among adults on the Navajo Nation were lower than those in other Native American adults of the Southwest in both adults under 45 years (0.018 vs 0.043%, $P < 0.0002$) as well as adults over 45 years (0.20 vs 0.27%, $P < 0.01$); however, the difference was less pronounced in adults over 45 years.

DISCUSSION

We found that the prevalence and incidence of ESRD among adults on the Navajo Nation are considerably higher than those in both the general US adult population and among all Native American adults in the US. The prevalence and incidence of ESRD are lower than those among other Native American adults of the Southwest, however.

Both the prevalence and incidence of ESRD on the Navajo Nation were higher in our study than in the study by Megill *et al.*¹³ from 1985. In the earlier study, the crude prevalence and incidence of ESRD among Navajos of all ages were 0.070 and 0.018%, respectively, compared with 0.49 and 0.083% in adults in our study. It is difficult to draw conclusions about temporal trends in ESRD burden on the Navajo Nation from these studies for two reasons. First, we only included adults in our analysis, whereas Megill *et al.*¹³ included adults and children. Second, the two studies used somewhat different data sources. (As we have performed in this study, Megill *et al.*¹³ calculated ESRD rates by dividing the total number of cases of ESRD among Native Americans living on the Navajo Reservation by the total population on the Navajo Nation. Rather than using United States Renal Data System (USRDS) data to determine the number of ESRD cases as we did, however, Megill *et al.*¹³ used three data sources – the ESRD Network 6 registry in Albuquerque, Indian Health Service records, and clinical records maintained by one of the study authors. Also, rather than using Census Bureau data to determine the population on the Navajo Nation as we did, they used data provided by a tribal statistician and demographer).

Much, but not all, of the disparity in rates of ESRD between the Navajo community and the general US population appears to be due to diabetes: we found that the age-adjusted prevalence and incidence of ESRD associated with diabetes were close to six times and 4.5 times those among the general US population, respectively.

Similarly, the age-adjusted prevalence and incidence of ESRD associated with diabetes were 1.7 times and 1.5 times that among Native Americans in the US, respectively. These findings are not surprising considering that the prevalence of diabetes mellitus type II has been shown to be higher among Navajos than in the general US population, as well as among all Native Americans in the US.^{4–6} One study found that the age-adjusted prevalence of medically diagnosed diabetes mellitus type II among Navajo adults was approximately 15% in 1991–1992¹⁴ (the most recent available data) compared with about 3% in the general US population in 1992^{14,15} and 11.5% among all Native Americans in the US in 1994.¹⁶

We also found that the prevalence of non-diabetic ESRD was higher on the Navajo Nation compared with the general US population and all Native Americans in the US: the age-adjusted prevalence of ESRD not associated with diabetes was close to two times that among both the general US population and among Native Americans in the US. Based on previous studies,^{9,17–21} the high rates of non-diabetic kidney disease among Navajos may be attributable to very high rates of glomerulonephritis, especially mesangial proliferative glomerulonephritis, which has been found among Southwest American Indian tribes, including the Navajo.^{18–21}

Interestingly, however, we found that the age-adjusted incidence of ESRD on the Navajo Nation not associated with diabetes was not significantly different from that in the general US population or among all Native Americans in the US. It is possible that these rates were not significantly different because of the small number of incident cases of non-diabetic ESRD. However, the incidence of ESRD not associated with diabetes was actually nonsignificantly lower on the Navajo Nation compared with the incidence in the general US population (0.19 vs 0.25%, $P < 0.20$). The fact that the prevalence, but not the incidence, of ESRD not associated with diabetes was greatly increased on the Navajo Nation compared with the general US population and all Native Americans in the US may suggest that the incidence of ESRD not associated with diabetes has decreased on the Navajo Nation in recent years relative to that in these other populations. Data from the USRDS indicate that the incidence of non-diabetic ESRD increased by about 1.5-fold between 1990 and 2001 among the general US population, supporting this hypothesis. It is also possible, though

unlikely, that people with non-diabetic ESRD live longer with the disease on the Navajo Nation than they do in the other populations.

Although certain Southwest tribes such as the Zuni are known to have extraordinarily high rates of kidney disease – we did not expect that the rates of ESRD on the Navajo Nation would approach the rates in the Zuni community – we were surprised to discover that the rates of ESRD among adults on the Navajo Nation were lower than the rates among other Southwest Native American adults. Much of the difference in ESRD rates between the Navajo Nation and other Native Americans in the Southwest appears to relate to diabetes: the prevalence and incidence of ESRD associated with diabetes on the Navajo Nation were 41 and 36% lower than among other Native American adults in the Southwest, respectively.

In terms of non-diabetic kidney disease, the age-adjusted prevalence was 1.3 times higher on the Navajo Nation compared with that among other Southwest Native Americans but the age-adjusted incidence was not significantly different between these groups. Again, the lack of a difference in incidence may be a statistical aberration due to the lower number of incident cases of non-diabetic ESRD. However, even though the difference did not reach statistical significance, our study suggests that the incidence of non-diabetic ESRD may be lower on the Navajo Nation than among other Southwest Native Americans (0.019 vs 0.025%, $P < 0.33$). Unless Navajos live longer with ESRD than other Native Americans in the Southwest, these findings suggest that the incidence of non-diabetic ESRD among other Native Americans of the Southwest may be rising relative to that on the Navajo Nation.

Finally, we calculated the incidence of ESRD on the Navajo Nation within several age groups and found that Navajo adults over the age of 45 are especially vulnerable to ESRD. For example, the incidence of ESRD was 1.5 times higher among adults on the Navajo Nation under the age of 45 compared with adults under the age of 45 in the general US population ($P < 0.19$, note that this difference does not reach statistical significance); however, the incidence of ESRD was 2.5 times higher among adults on the Navajo Nation over the age of 45 compared with adults over the age of 45 in the general US population ($P < 0.0001$). More work is needed to determine why this is the case.

Other factors besides the high rates of diabetes mellitus may contribute to the high rates of ESRD among Navajo adults. One such factor may be socioeconomic disparities between the Navajo community and the general US population as well as among all Native Americans in the US. According to Census Bureau data from 2000, 37% of Navajos live in poverty compared with 12% in the general US population and 25.7% among all Native Americans in the US.²² Additionally, average annual earnings among Navajos are \$10 000 per year lower than those of Americans in the general population and \$2,500 lower than those of all Native Americans in the US.²² And in almost 25% of Navajo

households, English is spoken only poorly compared with about 8% of total US households and about 10% of all Native American households in the US.²² Although all Navajos are eligible for health care at Indian Health Service facilities, socioeconomic factors may interfere with the ability of Navajo tribal members to access health care, which may contribute to the high rates of kidney disease and kidney disease risk factors such as diabetes and hypertension on the Navajo Nation. For example, financial concerns may make travel to health clinics more difficult, and language barriers may complicate the management of chronic conditions like diabetes and hypertension.

Socioeconomic disparities may also contribute to the elevated rates of ESRD among Southwest American Indians besides the Navajo. Per capita income is even lower among several other Southwest American Indian tribes than it is on the Navajo Nation. For example, per capita income is \$6133 on the Gila River Reservation and \$6976 on the Zuni Pueblo compared with \$7269 on the Navajo Nation.²³

Additionally, previous studies have suggested that genetics play an important role in the development of both diabetic^{24,25} and non-diabetic kidney disease.^{26,27} A genetic predisposition to kidney disease among the Navajo as well as other American Indian tribes cannot be ruled out.

There are limitations to our study. First, because the USRDS does not provide data broken down by tribe, we determined the prevalence and incidence of ESRD among all Native Americans living on or near the reservation, regardless of tribal affiliation. This could cause an over- or underestimate of the prevalence and incidence among Navajos if non-Navajo Native Americans living on or near the reservation have much higher or lower rates of kidney disease, respectively, than do Navajos. We do not believe that this is likely to be a significant source of error because approximately 90% of Native Americans living within the Navajo Service Area are Navajo. Other indigenous groups that live within the Navajo Service Area include Zuni, Apache, Cherokee, Sioux, and Yuman Indians.²⁸

Second, the zip codes used by the USRDS do not correspond exactly to the Zip Code Tabulation Areas (ZCTAs) used by the Census Bureau.²⁹ We believe the impact of this discrepancy is likely to be small. First, ZCTAs are intended to correspond closely to zip codes. Second, people living in a ZCTA who do not correspond to their zip code are typically assigned to an adjacent ZCTA. Only along the border of the study area might individuals be incorrectly included or excluded from the population total. Third, we cannot think of any reasons why geographic differences between ZCTAs and zip codes would introduce a differential bias.

A third potential limitation of this study is that we calculated the number of cases of ESRD on the Navajo Nation using 2001 ESRD data, the most recently available validated data, however we used data from Census 2000 to estimate the Navajo population. We did this because the Census Bureau only reports data from major census years.

Changes in the demographics of the Navajo population between 2000 and 2001 may have lead to an error in the results. However, it is unlikely that these changes would have been large enough to have caused significant inaccuracies.

In conclusion, ESRD is much more common among Native American adults living on or near the Navajo Nation than in the general US population or among all Native Americans in the US. Ongoing efforts to prevent diabetes mellitus and its long-term complications are important to reduce the disparate burden of morbidity, mortality, and health care utilization from ESRD in this high-risk population. In particular, initiatives like the National Diabetes Education Program,^{30,31} jointly sponsored by the Centers for Disease Control and Prevention and the National Institutes of Health, as well as locally organized efforts, such as the Healthy Path Nutrition and Physical Activity Program for Navajo Elders,³² will be valuable for reducing the rates of diabetic kidney disease.

More work is needed to understand why the prevalence (but not the incidence) of non-diabetic ESRD is elevated among Native American adults living on the Navajo Nation. A first step might be to better characterize the types of non-diabetic kidney disease from which Native Americans on the Navajo reservation suffer. To this end, further studies like the one conducted by Smith *et al.*²¹ in which clinical ESRD is correlated with pathological diagnoses might be helpful. At the same time, more work is needed to assess whether socioeconomic, cultural, geographic, genetic, or other factors may contribute to the elevated rates of non-diabetic kidney disease in this population.

Finally, this study provides a new approach for calculating rates of ESRD in relatively large geographic areas like the Navajo reservation. To our knowledge, no previous authors have used USRDS prevalence and incidence data to calculate disease rates over geographic regions conforming to ZCTAs. The approach we used would be applicable for determining ESRD rates in other large geographic regions such as metropolitan areas or other large Indian Reservations.

MATERIALS AND METHODS

Study population

The Navajo Nation is a 16 million acre area in Arizona, New Mexico, and Utah with more than 200 000 inhabitants; it is one of the largest federally recognized tribes in the US. Health care is provided to Native Americans by the Indian Health Service. The Navajo Area of the Indian Health Service, which serves the geographic region approximating the Navajo Nation, includes 82 zip codes on or adjacent to the Navajo Nation (see Figure 1). Approximately, 90% of the Native Americans who live in these 82 zip codes identify themselves as Navajo through 'tribal affiliation or community attachment'.²⁸

Study design

We used the USRDS database to determine the number of Native American adults ≥ 18 with ESRD who reside in one of the 82 zip codes that are part of the Navajo Service Area.³³ We used the same database to determine the number of new, or incident, cases of ESRD among Native American adults ≥ 18 living within the Navajo Service Area per year. Of note, the USRDS does not provide data on individual tribal affiliation. We then determined how many of these patients had ESRD associated with diabetes and how many were on dialysis (as opposed to transplant recipients). We used data from

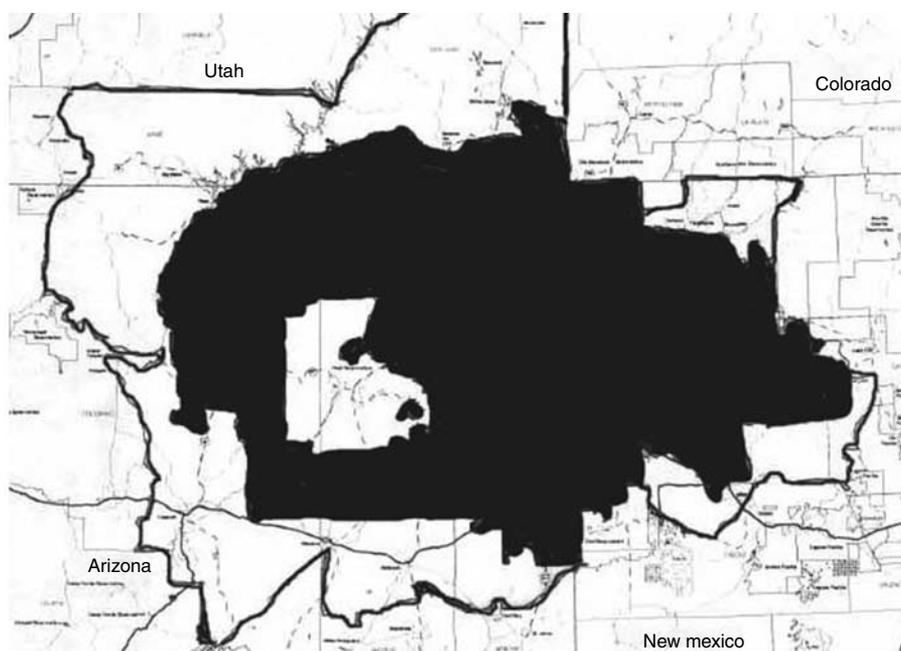


Figure 1 | Map of the Navajo Service Area.³⁷ The blackened area represents the Navajo Reservation, which is approximately 16 million acres in size. The Hopi Reservation, approximately 1.6 million acres in size, is the white area enclosed within the Navajo Reservation. The black line surrounding the reservation demarcates the 82 zip codes that make up the 'Navajo Service Area' (see text for an explanation of the 'Navajo Service Area'). Zip codes located within Hopi territory are not part of the Navajo Service Area.

2001, because this is the most recent year for which validated data are available.

For the denominator in the prevalence and incidence calculations, we estimated the population of Native Americans living within the Navajo Service Area using Census Bureau data from Census 2000. The Census Bureau does not report data by zip codes, but rather by ZCTAs, which are a close approximation of zip codes that correspond to census-defined blocks of land rather than postal service boundaries. A detailed description of ZTCAs can be found at <http://www.census.gov/geo/ZCTA/zctafaq.html>. Using the Census Bureau's American FactFinder program, we determined the number of Native Americans adults ≥ 18 who live in the 82 ZCTAs that make up the Navajo Service Area.²⁸

We estimated the crude prevalence and incidence of ESRD by dividing the total number of Native American adults with ESRD who live in the Navajo Service Area zip codes by the total number of Native American adults who live in the Navajo Service Area ZCTAs. The prevalence and incidence were age-adjusted to the 2000 US population using the direct method³⁴ using the age categories 18–24, 25–34, 35–44, 45–64, and ≥ 65 .

For comparison, we calculated the 2001 crude and age-adjusted prevalence and incidence of ESRD in a similar manner in the general US adult population among Native American adults in the US, and among Native American adults living in Arizona, New Mexico, Utah, and Colorado excluding those living on the Navajo Nation.³⁵

We used two-tailed Z-tests to compare the age-adjusted prevalence and incidence of ESRD on the Navajo Nation with those calculated in each of the other populations.³⁶ We used two-tailed Z-tests to compare the age-stratified rates among the populations as well.

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