END STAGE RENAL DISEASE (ESRD) DIALYSIS WORKFORCE STUDY IN THE U.S.

by

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A Thesis Submitted to the Faculty of the

DEPARTMENT OF PHARMACEUTICAL SCIENCES

In Partial Fulfillment of the Requirements

For the Degree of

MASTER OF SCIENCE

In the Graduate College

THE UNIVERSITY OF ARIZONA

2017

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ACKNOWLEDGEMENT

I hereby take this opportunity to acknowledge all those who have helped me during my thesis work and without whose support this thesis would not have been possible.

I am extremely grateful to my advisor Dr. Ivo Abraham for his valuable guidance and feedback in developing this thesis. I would also like to acknowledge my thesis committee members Dr. Akinlolu Ojo, Dr. Brian Erstad and Dr. Michael Katz for their support and comments for revising this thesis. I would also like to thank the American Society of Nephrology (ASN) for sharing some of their data and the University of Arizona Center for Health Outcomes and PharmacoEcononomic Research and University of Arizona College of Pharmacy Office of Graduate Programs for their help in providing resources for completing this thesis. Lastly, I am highly indebted to my family for their continuous support and encouragement throughout this process.

TABLE OF CONTENTS

List of Tables

List of Figures

ABSTRACT

Previous studies have shown that in the U.S., dialysis care has struggled with insufficient workforce to meet patient demand. In addressing this gap, the contribution of this study is that it goes beyond nephrologists workforce to include other dialysis workforce such as registered nurses (RNs) and advanced nurse practitioners (ANPs), licensed practical nurses (LPNs)/licensed vocational nurses (LVNs) and dialysis technicians in examining the effect of patient demand on the clinical responsibilities.

The study examines historical End Stage Renal Disease (ESRD) patient population levels and trained workforce levels to make predictions about future workforce levels needed to provide dialysis care for this population in the U.S. Forecasting analysis was first conducted to obtain patient demand and workforce supply estimates for 2030 using available historical data beginning 2008. These forecasted estimates were next used for the workforce scenario analysis to make predictions on the workforce supply in 2030 at the patient level and dialysis center level. The results from this study indicated that in 2030, a shortage of nephrologists and dialysis technicians and surplus of nursing workforce needs to be addressed to meet the estimated increase in dialysis patient demand.

Chapter 1

Introduction

1.1 Problem Statement

Nephrologists and registered nurses are the primary trained workforce for treating end stage renal disease (ESRD) patient population in the U. S[1,2]. The demand in specialized nephrology care will continue to increase with the increasing prevalence of ESRD in the U.S in the following decades[3,5,6]. Previous studies have shown that in the U.S., specialized nephrology care has struggled with an insufficient workforce to meet patient demand especially in dialysis care[3,4]. Studies have highlighted issues such as number of decreasing nephrologists, shortage of incentivized programs to recruit physicians and residents and the need for more training for nurses and technicians at the dialysis centers[5,6,21,23].

There is a gap in understanding how demand for dialysis care needs to be aligned with the supply of dialysis workforce such as nephrologists, registered nurses (RNs) and nurse practitioners (NPs), licensed practical nurses (LPNs) and licensed vocational nurses (LVNs), and dialysis technicians in the U.S. in the coming years. Current empirical evidence is limited because it has only identified that a supply shortage of nephrologists would occur[7,8,9] but does not explain how the shortage can meet the demand of the ESRD dialysis patients in the coming years in the U.S.

This study aims to address this research gap by quantifying the supply and demand levels in dialysis care in the coming years, for example 2030. This study is unique in that it goes beyond the role of nephrologists to include other dialysis workforce such as registered nurses (RNs) and advanced nurse practitioners (ANPs), licensed practical nurses (LPNs)/licensed vocational nurses (LVNs) and dialysis technicians in examining the effect of patient demand on the clinical responsibilities. Chapter 2 is a summary of literature on issues pertinent to dialysis work force in the U.S. Chapter 3 and 4 describe the methods and results for the forecasting analysis and workforce scenario analysis. Chapter 5 discusses key findings and their interpretation, options, recommended solutions, and limitations.

1.2 Research Objectives

i) The first objective is to estimate the demand of ESRD patients requiring dialysis for 2030.

ii) The second objective is to estimate ESRD workforce supply levels in the U.S. for 2030.

iii) The third objective is to align demand and supply across three major workforce categories in dialysis care in 2030 such as nephrologists, nurses and dialysis technicians.

1.3 Research Hypotheses

With evidence suggesting a critical need to measure the ESRD workforce supply with respect to the future ESRD patient population on dialysis treatments, it is hypothesized that there would be a change in patient workload both at the patient level and dialysis center level in the coming years. This would be calculated for 2030 as an example. Furthermore, it is hypothesized that there would be changes in both demand for and supply of dialysis workforce at the dialysis centers in the future.

Chapter 2

Literature review

2.1 Introduction

The purpose of this chapter is to summarize the gaps that previous ESRD literature has identified and key findings that will provide the background for the research objectives i)-iii) described in Chapter 1. These articles are limited to studies conducted in the U.S. only. Table 1 contains a detailed summary of the Author, Year, Journal, Type of Study, Title, and findings from these studies.

2.2. Literature Review on dialysis workforce issues in U.S.

End stage renal disease (ESRD) is the last stage (stage five) of chronic kidney disease (CKD)[1,2]. Dialysis is the only therapeutic option for ESRD patients other than getting a transplantation. CMS recommends that patients with a ESRD diagnosis should follow their healthcare team's advice regarding treatment[2]. In addition, it is also important for the dialysis workforce to provide care in a timely manner for ESRD patients to improve patient outcomes[2,10]. But the increasing ESRD population also creates

pressure on the dialysis responsibilities of the existing workforce, especially for nephrologists who are at the forefront. Providing comprehensive patient care to the ESRD population needs to be the main goal of predicting clinical needs [2,8,15,24].

In recent years, there has been a considerable number of qualified nephrologists retiring, that has created a burden on the current insufficient and inadequately trained renal physician workforce[16]. Also unlike cardiology, gastroenterology, and pulmonary medicine, procedural training requirements for nephrology are limited. After fellowships, very few nephrologists perform specialized procedures such as placement of peritoneal dialysis catheters, hemodialysis access interventions, and even kidney biopsies[3]. This is also because in the last decade or so, medical residents have been viewing nephrology as an unattractive specialty when compared with other internal medicine specialties[3,4,11]. This creates pressure to hire more dialysis nurses as an alternative to address the nephrology workforce shortage due to their knowledge and close involvement in caring for ESRD patients; which makes them ideal to work closely with nephrologists in caring for ESRD patients[21].

In addition, there are other reasons for the shortage supply in nephrology workforce. The domination of managed, capitated systems from a traditional fee for-service systems of care for the end-stage renal disease (ESRD) population has a significant impact on nephrology manpower needs[17]. Previously, traditional quality-of-care indicators for the ESRD population have included anemia control, patient survival and percentage of patients using arteriovenous fistulas[19], but with an increased need for

improving quality of clinical practice in the ESRD patients, studies have suggested hiring more physician alternatives to address shortage in supply of workforce.

Nephrologists working together with trained physician alternatives such as nursing staff, rehabilitation specialists, social worker, dietitian, renal administrator, technician/support staff, and health care coordinators would be able to reduce the heavy work load of nephrologists and renal physicians [19,23]. However, with few applicants applying for available nephrology fellowship positions and ESRD prevalence increasing[8,9], internal medicine residents need to have a greater exposure to nephrology during their training[9,10,11] and be able to work in dialysis care teams to improve ESRD patient outcomes.

With technology changes, the nephrology workforce especially nurses are expected to become technologically skilled[28] in providing care for the patient. In addition, factors such as challenges of the renal patient population, lack of role models, and perceived difficulty of the subject matter have played an influence in the lack of interest in not choosing nephrology as the subspecialty of choice[12]. Even though the number of nephrology fellowship programs and trainees has continued to increase slowly despite limitations in funding of graduate medical education[13], continued effort is required to engage students and residents in providing high-quality dialysis care as intelligent and compassionate nephrologists that are assisted by other dialysis workforce [14,15].

There is a need to study the impact of the slow fulfilment of the supply of renal physicians on the care delivery to ESRD patient population in the long term[17] as well as a

need to study current and future workforce trainees in nephrology[18]. Keeping this in mind, there have been several studies in the last two decades that calculated supply levels of nephrologists and ESRD prevalence. However, these studies are limited to the nephrologists workforce and do not study the supply of other workforce such as dialysis nurses and technicians. One study reported that though the supply of renal physicians increased more than 10-fold between 1970 and 1993, other factors such as the growth of managed care, the use of non-physician providers, and the implementation of other cost-cutting measures impact nephrologists' services to the ESRD population. One of the earliest studies in 1997 calculated that with a reduced mortality rate of ESRD patients at about 22% annually, and a decrease in the rate of growth of ESRD patients at about 8% annually, a minimum of 400 new nephrologists would be needed to maintain the current nephrologist-to-dialysis patient ratio in the next decade. Another study reported that between 1997 and 2010, there is a need to increase training rate by an additional 200 trainees per year for each of the next 14 years[18]. Also between 2009 and 2013, the number of residents registering for nephrology fellowships through the Electronic Residency Application Service[3] declined from 756 to 535.

George Washington University Health Workforce Institute recently published its new annual report[9] on the nephrology workforce prepared for ASN. One of the major findings of this report is that even though existing supply is not evenly distributed when compared to population need, there have been slight improvements in the nephrology workforce landscape. According to their findings, 430 new adult nephrologists per year being trained in the U.S. that is almost 2150 new adult nephrologists for a five-year period while the number of active nephrologists in each of the 5-year cohorts that are around

retirement age is around 1200. So, the inflow has been considerably higher than the outflow of nephrologists in the last few years. In addition, the report also states that in ESRD Seamless Care Organizations (ESCO) designed to improve care in Medicare beneficiaries with ESRD, there needs to be additional hiring of RNs, nurse coordinators and physician assistants to free up nephrologists' time to provide better patient care. Hence, there appears to be a need to quantify the decreased interest in nephrology among internal medicine fellows[12] to understand how to attract more applicants to the National Resident Matching Program (NRMP) nephrology.

Studies have also found that clinical and educational competence needs to be expanded in continuing nursing education for nurses in renal care[26]. Dialysis nurses often face challenges in providing effective patient education because of their limited training in perceiving patient needs and learning capabilities[26,27]. Limited nursing staffing and educational resources are also some of the potential barriers to nurses contributing to improving dialysis care and patient outcomes [27].

Medical and nursing students should also be engaged in understanding that high-quality care needs to be provided by highly trained nephrology workforce[15]. The dwindling interest in nephrology as a career has been evident for nearly one decade and is a not sudden phenomenon[4]. ASN and the new ABIM Nephrology Subspecialty Board need to work together to broaden the training to understand the scope of the subspecialty[3]. The ASN Task Force on Increasing Interest in Nephrology Careers has been trying to implement strategies for increasing interest among students and residents such as improving the educational continuum in nephrology and increasing mentorship[4]. In addition, there need

to be changes to the continuing nursing education curriculum to include training for nurses how to improve patient education and help patients understand the dialysis care and what they need to do to better manage their health behavior[26].

The skills and commitment of current active nephrologists needs to be leveraged to spark interest in nephrology careers among the talented students and residents entering medical schools and training programs[13,22] before there is a significant gap in the number of retiring nephrologists and those entering the specialty. Managing this gap will be critical to sustain a workforce that is adequate to meet the projected demand for nephrologists[14]. With the new bundled system under Medicare, all the dialysis labs are performed by nephrologists, which creates a burden on the rest of the dialysis workforce in case of a shortage of nephrologists at the dialysis centers[2]. Hence, there need to be more combined efforts in both medicine and nursing to guarantee that nursing graduates and medical residents and fellows who complete training and enter the practice of nephrology as experts in the broad context of providing specialized nephrology care.

In addition, greater use of patient care technicians and physician assistants by nephrologists, hospitals, and dialysis centers would help address the shortage because they are trained to perform most of the tasks required to reduce the load on nephrologists and nurse providers in outpatient dialysis units [19,22,23]. Since, Medicare only pays for dialysis in most cases throughout the life expectancy and offers limited financial support for transplant patients, most ESRD patients are forced to be on constant dialysis. So, we need more nephrology workforce to improve the quality of care for these patients but

the question arises as to how many are needed with respect to the ESRD dialysis patients.

It is evident from literature that there is a rising concern in the nephrology community that future demand for ESRD dialysis care needs to be aligned with the future clinician supply. Hence, there is a need to reconcile projections for demand for ESRD dialysis care with workforce projections for nephrologists, nurses and dialysis technicians in the U.S.

Chapter 3

Methods

3.1. Introduction

This study builds on literature and evidence in Chapter 2 that there is a need to align future demand for ESRD dialysis care with the future supply of dialysis workforce.

3.2. Study population

3.2.1 Demand

The demand in dialysis care was studied among the ESRD population in the U.S. that requires constant care and monitoring when on dialysis at the dialysis centers.

3.2.2 Supply

The workforce of interest included nephrologists, registered nurses (RNs), advanced nurse practitioners (APNs), licensed practical/vocational nurses (LPN/LVNs) and patient care technicians providing dialysis care at the dialysis centers. This workforce was selected for two reasons. First, their employment numbers represent quality of care provided to dialysis patients at the dialysis centers in the U.S.[1,2] Second, they are the most specialized among the dialysis workforce having undergone some form of clinical training in providing dialysis care.

3.3. Data Sources

The primary data source for the study came from the United States Renal Data System (USRDS), a comprehensive database of all patient and facility level data on the ESRD patients in the U.S.[1] The USRDS 2016 report was used to extract raw data on dialysis patients, dialysis centers and employment data on registered nurses, advanced nurse practitioners, licensed practical/vocational nurses and patient care technicians. Because the USRDS report did not capture data on nephrologists as providers at dialysis centers, the data on nephrologists was instead obtained from the American Society of Nephrology (ASN) from their list of certified members with MD/DO.

3.4 Measures

3.4.1 Demand

Data from 2008-2014 on the number of dialysis patients and number of dialysis centers for each year from the USRDS report was used to calculate future demand. This included dialysis patients at both certified facilities and Veterans Administration (VA) facilities. Similarly, the data on dialysis centers used in this study included both certified and VA facilities.

3.4.2 Supply

Workforce employed in dialysis care was measured using ASN data on nephrologists with MD/DO from 2008-2016, USRDS provider data on registered Nurses (RNs) full time and part time from 2008-2014, USRDS provider data on advanced Practice Nurses full time and part time from 2008-2014, USRDS provider data on licensed Practical

Nurses/Licensed Vocational Nurses (LPNs/LVNs) full time and part time from 2008-2014 and USRDS provider data on patient care technicians full time and part time from 2008-2014.

3.4.3 Other **assumptions** made in this study are:

a. Due to the lack of ASN data prior to 2008, for consistency in calculations both ASN and USRDS data measures were assumed beginning 2008.

b. The workforce data obtained from USRDS on RNs, APNs, LPN/LVNs and patient care techs was calculated as **full time equivalents (FTEs)** for better estimation and consistency. As the USRDS captures data on both part time employees and full time employees, these were all converted to full time equivalent (FTEs) employees for each workforce.

c. To achieve consistency, RNs and APNs data were combined as the professional nursing workforce category in this study; LPNs/LVNs and patient care technicians data has been combined as the dialysis technicians workforce in this study.

3.5 Data Analysis

The following analyses were conducted.

3.5.1 Forecasting Analysis

For this study, forecasting, also called 'estimating in unknown situations'[25,29,37] was performed using time series modeling. As the goal of this study was predicting the future values based on the inertia of the most current data, autoregressive integrated moving

average (ARIMA) appeared to be the best method to calculate point estimates for 2030. In the ARIMA model, the series to be forecast is expressed as a function of previous values of the series (autoregressive terms) and previous error terms (moving average terms) which are integrated together [37].

ARIMA was selected over regression because in the time series data selected for this study, each of the observations were related to each other and represented the same phenomena over time[35]. The time series modeling was conducted using IBM SPSS Statistics 24 expert modeler as this helps choose the best fitting ARIMA model. When this expert modeler program automatically chooses the best fitting ARIMA model, it helps eliminate trial and error that comes with choosing the best fitting model manually[25]. The same ARIMA model was applied to all the variables of interest to calculate their individual forecast estimates for 2030. After the forecasting analysis was performed, the goodness of fit estimates for the forecast model for each of the measures were calculated. These included the coefficient of determination (R^2), stationary R^2, root mean squared error (RMSE), mean absolute percentage error (MAPE), mean absolute error (MAE) and normalized Bayesian Information Criterion (BIC). The following definitions of the goodness of fit measures were used in this study. The R^2 measures the proportion of total variance that is explained by the model while stationary R^2 compares the stationary part of the model to a simple mean model[25]. The MAE is the average error when ignoring signs and MAPE is the average of the absolute values of the percentage errors [32,32]. The RMSE is the square root of the mean squared error i.e. sum of the squared forecast errors for each of the observations divided by the number of observations [25,37]. Normalized Bayesian

Information Criterion (BIC) is a general measure of the overall fit of the model, based on the mean square error[25].

3.5.2. ESRD workforce analysis

The forecast estimates derived from the forecasting analysis in 3.5.1 were used in this analysis.

3.5.2.1 To calculate the workforce at the patient level and dialysis center level:

a. First, to calculate the patient workload the patient to clinician ratios, for each of the workforce categories such as nephrologists, nurses and technicians were calculated for the most current year 2014 and future year 2030. The ratios calculated for each year included patients: nephrologist; patients: nurse; patients: technician. For 2014, the ratios were obtained by dividing the 2014 data on ESRD dialysis patients by the respective clinician data for that year. For 2030, each of the ratios were calculated by dividing the forecast estimate of ESRD dialysis patients by the respective clinician forecast estimates.

b. Second, to study the workforce at the dialysis center level, the clinician: dialysis center ratios for each of the workforce categories such as nephrologists, nurses and technicians were calculated for 2014 and 2030. The ratios calculated included nephrologist: center; nurse: center; technician: center. For 2014, the ratios were obtained by dividing the 2014 clinician data for the respective workforce by the data on ESRD dialysis centers for that year. For 2030, the ratios were calculated by dividing the forecast estimates for each of the clinicians in 2030 by the forecast estimate for dialysis centers for that year.

3.5.2.2 Standardized workforce comparisons

To compare the operationalization of the dialysis workforce trends with respect to time, the forecast estimates for the three workforce categories were standardized per 100,000 ESRD patient population. The workforce ratios nephrologists/100,000 ESRD dialysis patients, nurses/100,000 ESRD dialysis patients and technicians/100,000 ESRD dialysis patients were calculated and compared. This helped to compare the clinician workforce employment numbers at the dialysis centers with respect to one another.

3.5.3. Scenario analysis

This analysis was conducted in Excel modeling spreadsheets using Microsoft Office 2016 to calculate the 2030 workforce supply based on the forecasted demand and assuming same practice patterns in dialysis care as 2014. This was designed to calculate the differential in supply for each of the three workforce categories in 2030. The sign of the differential for each of the workforce determined whether a shortage or a surplus is predicted in 2030.

First, the forecast estimate of each of the clinician workforce for 2030 and the patient: clinician ratios for 2014 were used to calculate total patients in dialysis care. Next, this was used along with the patient: clinician ratios for 2030 to estimate the projected clinician supply in 2030. Finally, the differential of the projected clinician supply in 2030 at the 2014 practice patterns and the forecasted clinician supply for 2030 was calculated for each of the three workforce categories. The reason behind conducting this analysis

assuming same practice patterns as 2014 is that this is the most current workforce data representing current practices in dialysis care.

3.6 Additional Analysis

Growth Rate calculations

Average Annual Growth Rates (AAGRs) were calculated to study the change in growth of dialysis patients, dialysis centers, nephrologists, nurses and dialysis technicians over time from the starting year to the final year over a specified period. The AAGRs were calculated for:

i) the most current data (2008-2014 for ESRD dialysis patients, dialysis centers, FTE nurses and FTE technicians, and 2008-2016 for nephrologists)
ii) and forecasted data (2014-2030 for ESRD dialysis patients, dialysis centers, FTE nurses and FTE technicians, and 2016-2030 for nephrologists)

These were the steps in the AAGR calculations:

i) First, the net increase over the period is calculated followed by the average increase over the period.
ii) The average increase and the starting year values were then used to calculate the AAGR for that specific period.

The results from the individual analyses are reported in Chapter 4 along with the tables and figures.

Chapter 4

Results

This chapter reports the results from the forecasting analysis, workforce analysis, workforce projections from scenario analysis and growth rate calculations.

4.1 Demand and Supply Forecast estimates in ESRD dialysis care

Table 2 contains the results from the forecasting analysis. The forecasted demand estimates for ESRD dialysis patients and dialysis centers and forecasted supply estimates of nephrologists, FTE nurses and FTE technicians workforce along with their respective lower and upper confidence limits are reported. The forecast estimate for ESRD dialysis patients for 2030 was 689,693 (95% CI: 685,098-694,289). Similarly, the forecasted estimate for dialysis centers in 2030 was 9,911 (95% CI: 9,764-10,058). On the supply side, the forecasted estimate for nephrologists in 2030 was 13,107 (95%CI: 11,722-694,289), the forecasted estimate for FTE nurses in 2030 was 51,381 (95% CI: 50,647-52,115) and the forecasted estimate for FTE technicians in 2030 was 62,243 (95% CI: 60,993-63,493).

The goodness of fit statistics such as R^2, stationary R^2, RMSE, MAPE, MAE and normalized BIC are presented in Table 3. For the ESRD dialysis patients variable, the ARIMA model goodness of fit measures were R^2 and stationary R^2 of 0.99, MAE of 1364.94, MAPE of 0.32, RMSE of 1787.69 and normalized BIC of 15.53. Similarly, for the ESRD dialysis centers variable, the ARIMA model goodness of fit measures were R^2 and stationary R^2 of 0.99, MAE of 38.67, MAPE of 0.63, RMSE of 57.28 and normalized BIC of 8.65. On the supply side, the goodness of fit measures for the ARIMA model for nephrologists were R^2 and stationary R^2 of 0.65, MAE of 449.70, MAPE of 5.68, RMSE of 585.79 and normalized BIC of 13.23. Similarly, for FTE nurses variable, the goodness of fit measures for the ARIMA model were R^2 and stationary R^2 of 0.99, MAE of 162.80, MAPE of 0.61, RMSE of 285.50 and normalized BIC of 11.86. Also for the FTE technicians variable, the goodness of fit measures for the ARIMA model were R^2 and stationary R^2 of 0.97, MAE of 330.23, MAPE of 0.86, RMSE of 486.34 and normalized BIC of 12.93.

4.2. ESRD dialysis workforce analysis

This analysis was performed using the forecast estimates to calculate the workload at the patient level and dialysis center level. Table 4 contains the results for the patient: clinician ratios and clinician: center ratios for each of the workforce as an average across the patient population based on their FTE responsibilities. At the dialysis centers, the results indicate that patient workload for one nephrologist was 51.1 in 2014 and would be 52.6 in 2030. The patient workload for FTE nurse was 14.9 in 2014 and will be 13.4 in

2030. The patient workload for one FTE technician was 10.7 in 2014 and will be 11.1 in 2030. Figure 2 shows the graphical representation of the ratios. Similarly, the FTE employment at each center in 2014 was 1.3 nephrologist/center, 4.6 nurses/center and 6.4 technicians/center. In 2030, the FTE employment at each center would be 1.7 nephrologist/center, 5.2 nurses/center and 6.3 technicians/center.

In addition, the standardized data was used to compare operationalization of the dialysis workforce trends with respect to time. The nephrologists/100,000 ESRD dialysis patients, nurses/100,000 ESRD dialysis patients, technicians/100,000 ESRD dialysis patients were calculated (Table 5 and Figure 3). In 2014, the nephrologists/100,000 ESRD dialysis patients were calculated to be 1958, nurses/100,000 ESRD patients were calculated to be 6708 and technicians/100,000 ESRD dialysis patients were calculated to be 9367. Similarly, for 2030, the nephrologists/100,000 ESRD dialysis patients were calculated to be 1900, nurses/100,000 ESRD patients were calculated to be 7450 and technicians/100,000 ESRD dialysis patients were calculated to be 9024.

4.3 Scenario analysis

The results for the scenario analysis for 2030 (Table 6) showed a shortage of 386 nephrologists, surplus of 5679 FTE nurses and a shortage of 2276 FTE technicians in 2030 with respect to the demand of ESRD dialysis patients. The detailed calculations from the scenario analysis are reported in Appendix 2.

4.4 Additional Analysis: Growth rate calculations

The results from the Average Annual Growth Rate (AAGR) calculations are reported in Table 7. Based on the AAGRs for the demand side, the growth rate in the ESRD dialysis patient population has been 4.02 % between 2008 and 2014 and in the future, 3.11 % between 2014-2030. Similarly, the growth rate in the ESRD dialysis centers is 3.81 % between 2008 and 2014 and in the future, 2.92 % between 2014 and 2030. On the supply side based on the AAGRs, nephrologists workforce will experience a growth rate of 2.83 % between 2016 and 2030, the FTE nursing workforce will experience a growth rate of 4.14 % between 2014 and 2030, and the FTE technicians workforce will have a growth rate of 2.77 % between 2014 and 2030.

Chapter 5

Discussion

This chapter summarizes the key findings of the study and their interpretation, options, solutions recommended and limitations.

5.1 Key Findings and Interpretations

The results from forecasting analysis in this study showed an estimated growth of the ESRD dialysis population to 689,693 in 2030 from 460,675 in 2014. This included patients at certified dialysis facilities and VA facilitates. Similarly, the ESRD dialysis centers are estimated to increase to 13,107 in 2030 from 6,757 in 2014. The number of nephrologists is estimated to grow to 13,107 in 2030 from 8387 in 2016. Similarly, the number of FTE nurses is estimated to increase to 51,381 in 2030 from 30,903 in 2014. In addition, the number of FTE technicians is estimated to increase to 51,381 in 2030 from 30,903 in 2014.

Next, a discussion of the goodness of fit from the SPSS 'time series modeler'. The goodness of fit presented in Table 3 showed that all the forecasted estimates provided good absolute fit and forecast accuracy. An R^2 of 1 indicates that the regression line perfectly fits the data. In this analysis, the R^2 of 0.99 reported for ESRD dialysis patients,

dialysis centers and FTE nursing workforce variables indicates that 99% of the variance can be explained. Whereas R^2 of 0.97 for the FTE technicians variable indicates that 97% of the variance can be explained and R^2 of 0.65 for the nephrologists variable indicates that 65% of the variance can be explained. Based on the MAPE, the ARIMA model for ESRD dialysis patients variable had the best forecasting accuracy when compared to models for rest of the variables (i.e. a lowest value of MAPE). Based on the RMSE, the ARIMA model for the ESRD dialysis patients variable provided the best fit when compared to models for the rest of the variables (minimum value of RMSE indicates a good fit for the model). Based on the lowest value of the normalized BIC, the model for the ESRD dialysis centers provided the best fit compared to the fit of the models for the rest of the variables.

Additional growth rate calculations were conducted on the actual historical data and forecasted estimates to compare the current growth rate and estimated growth rate in 2030. The AAGR calculations showed that the estimated growth rate for the ESRD dialysis population, dialysis centers, nurses and technicians between 2014 and 2030 is less than the current growth rate for these measures. Similarly, the estimated growth rate for nephrologists between 2016 and 2030 is less than the growth rate between 2008 and 2016. One of the reasons for this could also be the reduction in the number of nephrologists between 2015-2016 that was evident from the data that ASN captured. This could have resulted from the decline in the number of nephrology fellowship positions that are filled.

The results from the workforce analysis for 2030 at the patient level and dialysis center level showed the change in patient workload for each clinician with respect to demand across the ESRD dialysis population. The patient workload of a single nephrologist based on their FTE responsibilities is estimated to be 52.6 ESRD dialysis patients in 2030, that is higher than 51.1 patients in 2014. The FTE patient workload of a single nurse would be 13.4 patients in 2030, when compared to 14.9 FTE patient workload in 2014. Similarly, the FTE workload responsibilities of a single dialysis technician would 11.1 in 2030, when compared to 10.7 in 2014. Furthermore, the standardized workforce results showed an estimated decline in nephrologists and FTE technicians when compared to FTE nurses in 2030.

As reported in Chapter 4, the major findings of the scenario analysis are that there would be an estimated shortage of 386 nephrologists and a shortage of 2277 FTE technicians in 2030. However, there would be a surplus of 5579 FTE nursing workforce in 2030. The different options and solutions recommended are based on these findings.

5.2 Options

This section discusses different options to address the feasibility of the supply-demand findings for 2030.

The first option would be to shift the clinical responsibilities of nephrologists downwards to the nursing workforce and shift the clinical responsibilities of the technicians upwards to the nursing workforce. The second option would be increasing

the number of nephrologists and dialysis technicians in response to their estimated shortage, while maintaining the nursing workforce.

The first option does not appear to be feasible because the scope of practice at the dialysis centers has been clearly defined for the workforce categories based on their training and clinical expertise. Nephrologists have advanced training and are the primary providers responsible for care during dialysis treatments. Nephrology nurses are responsible for assessing patients, ensuring that patients' medications are administered correctly and overseeing the dialysis process daily. Also, patient care technicians (PCTs) are responsible for starting and ending each treatment along with patient monitoring at the dialysis centers [2,29]. Therefore, the scope of work that nurses perform does not qualify to be the same workload as that of nephrologists.

Similarly, the scope of work that nurses perform does not qualify as the same workload as that performed by dialysis technicians. The clinical responsibilities and advanced training of both RNs and ANPs is different from the scope of practice of LPNs/LVNs and patient care technicians. The average annual salaries of RNs and ANPs based on their FTE responsibilities are different from the salaries of LPNs/LVNs and patient care technicians. Based on the Bureau of Labor Statistics (BLS) 2016 data[41], the 2016 median annual salary for RNs was $68,450 per year, median annual salary for LPNs/LVNs was $44,090 and median annual salary for patient care technicians was $31,387. So, the costs would be higher when RNs are paid their regular salary for taking up responsibilities that technicians would normally perform. Previous literature suggests that greater use of patient care technicians and physician assistants by nephrologists,

hospitals, and dialysis centers could help address the shortage [22,23], but based on the division of responsibilities and scope of clinical practice, it is not ideal for one workforce level to take up additional clinical responsibilities that would normally have been performed by another workforce.

The second option assumes that the clinical responsibilities cannot be shifted from one workforce to another and that the shortage has be addressed by increasing the number of clinicians in that specific workforce. This can be achieved by increasing the number of nephrologists and dialysis technicians. This also appears more feasible and applicable within the current scope of practice in dialysis care where each clinician has specific responsibilities. It is also important that this is done while maintaining the current nursing workforce level. The solutions in the next section have been proposed using this option.

5.3 Solutions

The results from this study indicate that the shortage in both nephrologists and dialysis technicians needs to be addressed through efforts to increase these workforce levels. This is also supported by evidence that specialized nephrology care has struggled with insufficient workforce to meet patient demand in the U.S.[10,12,18,21].

As the study results and prior literature both indicate, recruitment of physicians into nephrology needs to be increased and more fellows and residents need to go into nephrology. The number of National Resident Matching Program (NRMP) nephrology

matches need to be increased to attract more fellows to this specialty. The ASN 2016 workforce report findings state that the number of adult nephrology matches has been low compared to the previous decade[10]. According to the 2017 NRMP report[38] on fellowship Matches in the Specialties Matching Service, 284 out of 467 positions in nephrology were filled. In addition, the specialty had the lowest proportion (57/294 i.e. 22.5%) filled by graduates of U.S. allopathic medical schools. However, nephrology was among the top five specialties in both percentage of positions filled by non-U.S. citizen graduates of international medical schools are Nephrology (128/294 i.e. 45.1%) and percentage of positions filled by U.S. citizen graduates of international medical schools (57/294 i.e. 20.1%).

From the findings in the NRMP report, it is evident that nephrology does not provide enough incentives as an area of specialization for most U.S. graduates. This will be possible through efforts to engage medical students in nephrology as a specialty by making changes to the educational continuum such as recognizing nephrology educators, increasing faculty development and providing more grants and travel support for physicians-in-training during ASN Kidney Week[4,5,13,14]. Nephrologists also need to act as mentors to any prospective renal fellows, helping them navigate through medical school to internal medicine residency which would help create more new nephrologists[5,14]. As more and more nephrology residency positions are being by filled non-U.S. citizens that are graduates of international medical schools, these clinicians become established in the U.S. and choose not to return to their native country[30]. This loss of local talent creates "brain drain"[40]. This can be addressed through international efforts at providing specialist nephrology training coupled with incentive programs that

would increase the likelihood that these trained nephrologists will return to their native country and help improve global kidney care[30,40].

The common perceptions among medical students and residents that nephrology is not challenging if not boring and that nephrology job opportunities are dim[5], also need to be addressed by improving the nephrology elective structure and engaging more residents in scholarly activities to increase their engagement in clinical research[12,14] leading to presentations at national and state level. In addition, dialysis facilities need to increase their hiring of nephrologists and offer attractive salary packages for these nephrologists to continue providing their services to patients at the different dialysis centers.

Dialysis technicians need to be hired in more numbers and need to be provided with better training. Providing incentives such as loan repayment and bonuses will help recruit more LPNs/LVNs and patient care technicians into dialysis care. Also, introducing formal continuing education with contact hours at the dialysis facilities will help their professional growth. Even though most facilities do not differentiate between hemodialysis technicians with years of experience versus those at entry level, increased expertise builds active engagement with patients and leads to increased professional growth of the technician workforce[39]. It is important to ensure that the patient care technicians have the right qualifications, have been trained adequately to perform their responsibilities at the dialysis facilities and comply with the policies at the different dialysis units. This can only be achieved through more strategic partnerships between dialysis facilities and both public and private colleges.

Also, it is important to ensure that there is no attrition in the exiting nursing workforce due to burnout and maintain enough nurses such that a shortage does not occur because of significant numbers leaving the workforce. This study results show that there would be an increasing demand for more supply of the nephrology workforce in the future, that is also supported by the three major dialysis organizations that report that they do not anticipate a fall in their demand for nephrologists in the future years[9,10].

5.4 Limitations

Several limitations are discussed in detail. One of the limitations of this study is that this did not control for the fact that nephrologists and some of the nursing workforce spend time on other services in additional to providing dialysis care. It was difficult to determine the exact division of all their clinical responsibilities at each dialysis center. Another important limitation is that there was no data on the percentage of nephrologists working in ICU critical care nephrology. There was no available data on the numbers of double boarded physicians for each year of the past 10 years. In addition, competition between the major dialysis providers often leads to nephrologists trying to move their patients across dialysis units[9,10]. Also, this study did not control for patients that could have been double counted or moved to a different dialysis unit in between their dialysis treatments. In addition, there was no data on the state-wide variations in the workforce at the dialysis centers, which limited the potential to incorporate this in the study.

5.5 Conclusion

These projections have implications in the assessment of ESRD patient outcomes by 2030. Currently, ESRD is the only disease that is covered by Medicare regardless of age. The Medicare ESRD Program implemented bundled payments in 2011 and the first pay-for-performance system in 2014[2,15]. To ensure the success of providing high-quality care in this novel payment system, the U.S. needs an adequate supply of nephrologists[7] along with the other trained workforce. In the new ESRD Seamless Care Organizations (ESCO) designed to improve team based care in Medicare beneficiaries with ESRD[9,10], there needs to be additional hiring of other workforce levels to free up nephrologists' time to provide better patient care.

The results from this study show that the number of nephrologists and dialysis technicians (LPNs/LVNs and patient care technicians) need to be increased to meet the demand of the ESRD dialysis population in the U.S. Incorporating the solutions recommended in this study would address the workforce at the dialysis facilities required to meet the demand of the ESRD dialysis patients. In addition to estimating supply of nephrologists workforce, this study also included other dialysis workforce such as registered nurses (RNs) and advanced nurse practitioners (ANPs), licensed practical nurses (LPNs)/licensed vocational nurses (LVNs) and dialysis technicians to understand the right size of the dialysis workforce to meet the ESRD dialysis patient demand in 2030.

Table 1 Selected literature on ESRD workforce issues in the U.S.

Author	Year	Journal	Type of Study	Title	Findings
Adams[16]	2012	Clin J Am Soc Nephrol	Editorial	Attracting More Residents into Nephrology	Reports that instead of alienating them, they should be engaged in understanding that the future of the patients requires high-quality care provided by intelligent and compassionate nephrologists and assisted by other health care personnel
Anderson et al[23]	2009	American Journal of Kidney Diseases	Editorial	Role of Physician Assistants in Dialysis Units and Nephrology	Physician assistants can perform most of the tasks required to reduce the load on nephrologists in outpatient dialysis units. Hence the study reports that greater use of physician extenders by nephrologists, hospitals, and dialysis centers would help address the shortage
Berns[3]	2014	Clin J Am Soc Nephrol	Commentary	Training the next generation's nephrology workforce	ASN along with the new ABIM Nephrology Subspecialty Board need to work together to broaden the training to understand the scope of the subspecialty. The number of residents registering for nephrology fellowships through the Electronic Residency Application Service declined, Berns reports that this must be paid attention to as nephrology trainees are losing interest in the subspecialty and need to understand that they do add value to patient care and disease management.
Friedman[11]	1997	Nephrol Dial Transplant	View	Grim projections for American nephrologists	As nephrologists keep decreasing, with increasing ESRD and too few applicants are applying for available nephrology fellowship positions, this creates an alarm

Author	Year	Journal	Type of Study	Title	Findings
Glassock[7]	1997	American Journal of Kidney Diseases	Perspective	American nephrology in 2010: Perspectives for its 50th anniversary	Reports that domination of managed, capitated systems from a traditional fee for-service systems of care for the end-stage renal disease (ESRD) population will have a significant impact on nephrology manpower needs
Jhaveri et al[12]	2012	American Journal of Kidney Diseases	Special article	Enhancing Interest in Nephrology Careers During Medical Residency	This study found that one of the major reason is due to limited nephrology exposure that internal medicine residents have during their training. This needs to be addressed as interest in nephrology as a career is critical to sustain a workforce adequate to meet the projected demand for nephrologists
Jhaveri et al[14]	2013	American Journal of Kidney Diseases	Special research article	Why Not Nephrology? A Survey of US Internal Medicine Subspecialty Fellows	The survey results showed that factors such as the challenges of the patient population, lack of role models, lack of procedures, and perceived difficulty of the subject matter played an influence in the lack of interest in not choosing nephrology as the subspecialty of choice
Kletke[17]	1997	Am J Kidney Dis	Special article	The changing supply of renal physicians	This article reports that long-term increases in the demand for nephrologists would be affected by growth of managed care, the use of non-physician providers, and the implementation of other cost-cutting measures that impact the delivery of services to the ESRD population.

Author	Year	Journal	Type of Study	Title	Findings
Nielson et al[18]	1997	Journal of the American Society of Nephrology	Report	The Ad Hoc Committee report on estimating the future workforce and training requirements for nephrology	The survey results showed that between 1997 and 2010, there is a need to increase training rate by an additional 200 trainees per year for each of the next 14 years.
Parker et al[5]	2012	Clinical Journal of the American Society of Nephrology	Public Policy Series Report	The Future Nephrology Workforce: Will There Be One?	Parker et al recommend that ASN Task Force on Increasing Interest in Nephrology Careers needs to implement strategies for increasing interest among students and residents such as improving the educational continuum in nephrology and increasing mentorship
Pogue et al[15]	2002	J Natl Med Assoc.	Review	Kidney disease physician workforce: where is the emerging pipeline?	There is a need to recruit and train adequate numbers of renal physicians in comprehensive patient care to meet future clinical needs
Rosenberg[13]	2014	Journal of the American Society of Nephrology	Editorial	It Takes a Spark to Light a Fire: Kindling Interest in Nephrology Careers	Need to increase interest in nephrology careers among the talented students and residents entering medical schools and training programs

Author	Year	Journal	Type of Study	Title	Findings
Rosenberg[22]	2007	Journal of the American Society of Nephrology	Editorial	Adult nephrology fellowship training in the United States: Trends and issues	The growth in nephrology fellowship programs is not large enough to meet previously estimated workforce needs from the ASN report published in 1997
Steinman[20]	1999	Am J Kidney Dis	Editorial	Nephrology workforce shortfall: solutions are needed	Nephrologists must work together with nursing staff, rehabilitation specialists, social worker, dietitian, renal administrator, technician/support staff, and health care coordinator to deliver quality care to the ESRD patient.
Suki[21]	1999	Am J Kidney Dis	Editorial	Are physicians' assistants the answer to a shortage of nephrologists?	Dialysis nurses are the most knowledgeable and most intimately involved in caring for ESRD patients.
Wolfe[19]	2011	Am J Kidney Dis	Special Article	Adequacy of Dialysis Clinic Staffing and Quality of Care: A Review of Evidence and Areas of Needed Research	Professional staffing of dialysis clinics needs to be prioritized to improve outcomes in the ESRD population

Table 2. Forecasted estimates using ARIMA

For 2030

	Point estimate	**Lower CL**	**Upper CL**
ESRD dialysis patients	689,693	685,098	694,289
ESRD dialysis centers	9,911	9,764	10,058
Nephrologists	13,107	11,722	14,492
FTE Nurses	51,381	50,647	52,115
FTE Technicians	62,243	60,993	63,493

Table 3. Fit statistics

Fit Statistic	**ESRD dialysis patients**	**ESRD dialysis centers**	**Nephrologists**	**FTE Nurses**	**FTE Technicians**
Stationary R-squared	.99	.99	.65	.99	.97
R-squared	.99	.99	.65	.99	.97
RMSE	1787.69	57.28	585.79	285.50	486.34
MAPE	.32	.63	5.68	.61	.86
MAE	1364.94	38.67	449.70	162.80	330.23
Normalized BIC	15.53	8.65	13.23	11.86	12.93

Table 4. Results from workforce analysis

Year	Patients: nephrologist	Patients: FTE nurses	Patients: FTE technicians	Nephrologists/center	FTE Nurses/center	FTE Technicians/center
2014	51.1	14.9	10.7	1.3	4.6	6.4
2030	52.6	13.4	11.1	1.7	5.2	6.3

Table 5. Workforce standardized per 100,000 ESRD dialysis patients

Year	Nephrologists/100,000 ESRD dialysis patients	FTE nurses/100,000 ESRD dialysis patients	FTE technicians/100,000 ESRD dialysis patients
2014	1958	6708	9367
2030	1900	7450	9024

Table 6. Scenario analysis

Workforce	**2030 Differential**
Nephrologists	-386
Nurses	5679
Technicians	-2276

Table 7. Growth rate calculations using AAGRs (in %)

	Most current data **2008-2014** ***2008-2016**	**Forecasted data till 2030** **2014-2030** ***2016-2030**
ESRD dialysis patients	4.02	3.11
ESRD dialysis centers	3.81	2.92
Nephrologists	6.89*	2.83*
Nurses	5.45	4.14
Technicians	3.5	2.77

Figure 1. Workforce analysis at patient level and dialysis center level

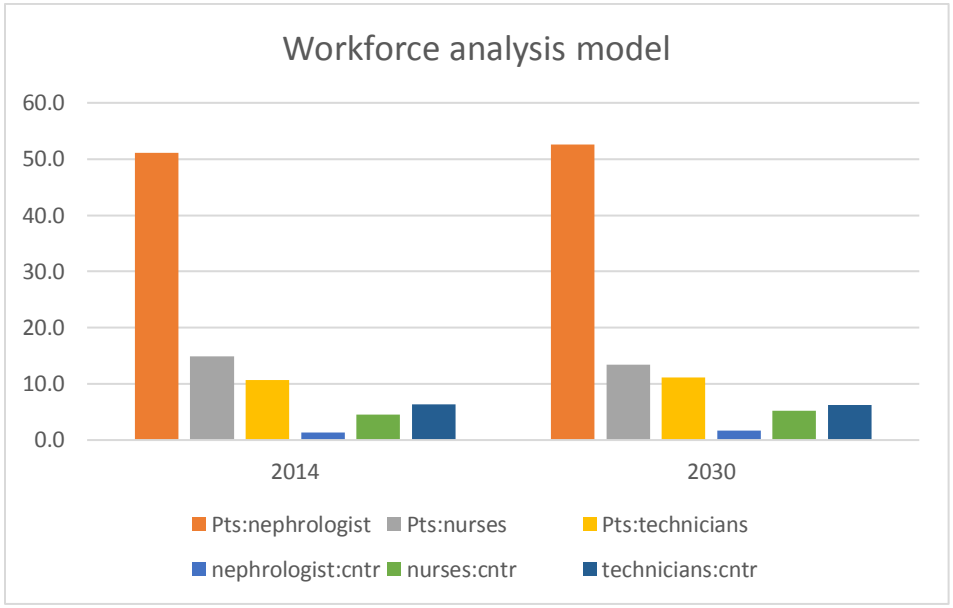
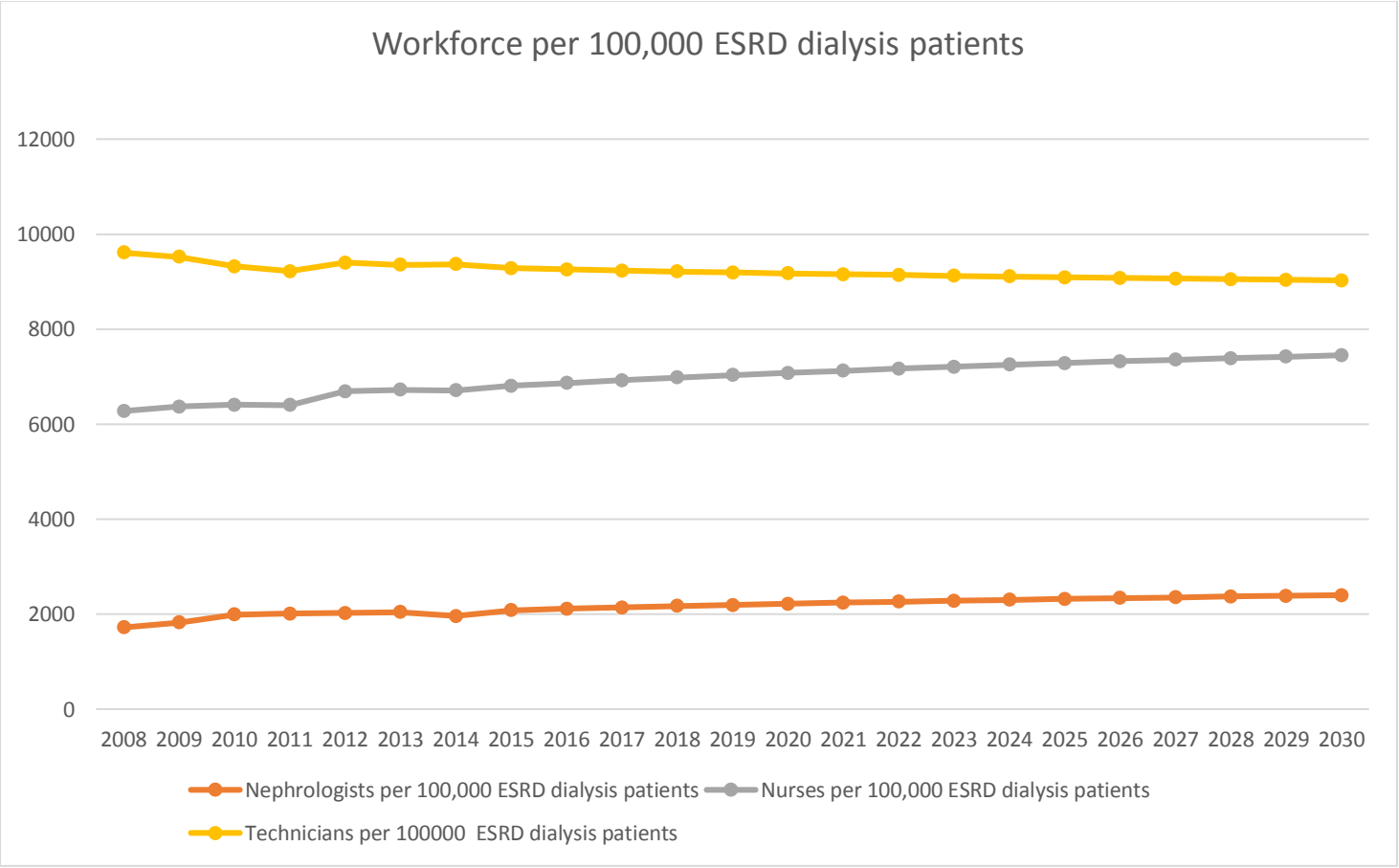


Figure 2: Graphical comparison of workforce standardized per 100,000 ESRD dialysis patients



APPENDICES

Appendix A: Final FTE Calculations

Year	FTE RNs	FTE Adv. Pract Nurses	FTE LPNs	FTE Techs	RNs+Adv pract nurses @FTE	LPNs+Techs @FTE
2008	23043	241	4641	31010	23285	35651
2009	24338	298	4676	32143	24636	36819
2010	25474	288	4711.5	32763	25763	37474
2011	26185	314	4611	33563	26499	38174
2012	28280	305	4577	35584	28585	40161
2013	29407	314	4575	36796	29721	41371
2014	30589	314	4577	38575	30903	43152

Appendix B: Scenario analysis calculations

For 2030	
Forecasted estimate for nephrologists	13107.3
pts/nephrologists 2014	51.1
Total patients in dialysis care @51.1 pts/nephrologists	669,422.6
pts/nephrologists 2030	52.6
Based on 2014 levels, projected nephrologists in 2030 @ 52.6 pts/nephrologists	12721.7
Differential	-386

Forecasted estimate for FTE nurses	51,381.4
pts/nurses 2014	14.9
Total patients in dialysis care @ 14.9 pts/nurses	765,936.3
pts/nurses 2030	13.4
Based on 2014 levels, projected FTE nurses in 2030 @ 13.4 pts/nurse	57059.9
Differential	5679

Forecasted estimate for FTE technicians	62,243.2
pts/technicians 2014	10.67
Total patients in dialysis care @10.67 pts/technicians	664,485.7
pts/technicians 2030	11.1
Based on 2014 levels, projected FTE technicians in 2030 @11.1 pts/technician	59,966.7
Differential	-2276

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