The Effect of Telemedicine on Neonatal Intensive Care Unit Length of Stay in Very Low Birthweight Infants

Mark C. Rendina1,2, M.S., M.S.

1 Department of Health Policy and Administration, School of Public Health
2 University of North Carolina Hospitals Information Services Division
University of North Carolina, Chapel Hill, NC

ABSTRACT

Objective: This study addresses the effect of the installation and use of a telecardiology system on the intensive care length of stay of very low birthweight (VLBW) newborn infants. Design: A retrospective comparison of 314 VLBW infants admitted to one of two neonatal intensive care units for a three year period from calendar years 1994 through 1996. A regression model was constructed to predict the intensive care length of stay while controlling for known risk factors. Results: Telemedicine's effect is to reduce the intensive care length of stay and is both statistically significant (p < 0.05) and practically significant, reducing the intensive care length of stay by over 17%. The reduction in length of stay is greater at lower birthweights. Conclusions: Under the circumstances present in this study, telemedicine has been an effective intervention to reduce the intensive care length of stay.

Key words: Telemedicine, health outcomes research, telecardiology, information systems evaluation, low birthweight, echocardiography

INTRODUCTION

Advances in neonatal care have dramatically improved the survival rates of VLBW infants. However, this improvement often requires contributions from a variety of pediatric subspecialists. While most of these subspecialists are found in large urban areas or academic medical centers, many infants are not born at or near such referral centers. At many institutions, the volume of patients requiring subspecialty support is insufficient to justify the high cost of on-site, full-time support. The choices facing clinicians caring for such infants are to locally treat an infant with less than optimal information and support, or to transfer such patients to an institution with such specialists for diagnosis and treatment.

Differentiating heart versus lung disease in VLBW requires the expertise of pediatric cardiologists to interpret neonatal echocardiograms and provide diagnostic and therapeutic assistance. During the study period, a telemedicine system for the interpretation of neonatal echocardiograms and inclusion of interactive video in cardiology case consultations became operational between the University of North Carolina and New Hanover Regional Medical Center. The hypothesis tested in this paper was whether the installation and usage of this system would decrease the morbidity of VLBW infants as measured by the neonatal intensive care unit (NICU) length of stay.

BACKGROUND

In the U.S., approximately 1% of all live newborn infants weigh less than 1500 grams (just over three pounds). These VLBW infants typically require stays of longer than a month. Neonatal intensive care is one of the most expensive forms of treatment in a hospital1, typically costing several thousand dollars per day.

Telemedicine is being studied as a way to bring subspecialty support to NICUs which lack subspecialty support. It is often promoted as a way to improve the quality of and access to medical care2,3. Telecardiology has been shown to dramatically reduce the turn-around time of neonatal echocardiogram interpretation4. By reducing time to diagnosis, thereby avoiding inappropriate therapies and beginning critical therapies more quickly, it may be possible to decrease morbidity. However, little is known about the consequences on health outcomes resulting from telemedicine5.

A previous study6 has indicated a statistically nonsignificant reduction in intensive care unit length of stay associated with the adoption of a
telemedicine system for the interpretation of pediatric echocardiograms. However, that study was limited in several ways. First, its sample size was insufficient to attain an acceptable level of experimental power. Second, the study did not control for known risk factors. Finally, the study design used did not allow adjustment for the increasing pressures to decrease length of stay. The present study addressed all three of these weaknesses.

METHODS

Definition of Intervention

New Hanover Regional Medical Center (NHRMC) is a 628-bed medical center located in Wilmington, North Carolina. Three neonatologists staff its 23-bed neonatal intensive care unit (NICU). On June 29, 1995 a telemedicine system began operations between the University of North Carolina and New Hanover Regional Medical Center. The system employed a full T-1 telecommunications leased line at a bandwidth of 1.544 megabits per second. Total capital costs of the system were approximately $45,000. The purpose of this system was to provide immediate turnaround of neonatal echocardiograms and include video during cardiology case consultations.

Mission Memorial Hospital (MMH) acted as a comparison institution. MMH is a 910-bed hospital with a 35-bed NICU staffed by four neonatologists. It was selected because, on the basis of a number of factors, it was judged to be the most similar NICU to NHRMC for which data were available. These factors included the availability of pediatric subspecialists, number of admissions, number of beds, number of neonatologists, birth profile, and transport characteristics to other hospitals. The service areas of the two institutions do not overlap.

Study Design

Because randomization was not feasible, a retrospective study design was employed. All single gestation infants (not twins, triplets, etc.) admitted to neonatal intensive care at NHRMC and MMH surviving until discharge were eligible subjects in this study. The study includes all such infants born between January 1, 1994 and December 31, 1996. In the cases where subjects were transferred to an academic medical center, the infants were followed-up at these institutions.

Data Sources

The primary data source was the North Carolina Neonatal Data Management System (NCNDMS). This is a database which collects information on all newborn infants admitted to neonatal intensive care in the state. The NCNDMS was supplemented with information from discharge summaries, medical records, appropriate logbooks and billing records.

Model Specification

The goal of the study was to determine the effect of telemedicine on the length of stay (LOS). Hospital charges were unavailable; however, data from a previous study indicate the correlation between total hospital charges and NICU LOS is very high ($r > 0.9$). The independent variables selected were fairly standard demographic predictors of neonatal morbidity: birthweight, gender, race (classified as white/nonwhite), gestational age, maternal age, and method of delivery. After review of the neonatal LOS modeling literature and consultation with the neonatologists and transfer coordinator, dummy variables for inborn (born at the institution in which they received intensive care) and respiratory therapy (whether an infant required mechanical ventilation) were added. Several variables that might have been useful predictors were not recorded in the database (insurance status and maternal substance abuse) or were dropped due to unreliable reporting (prenatal care).

Date of birth was included in the regression analysis to allow for the possibility that LOS is decreasing with time. For example, an infant born in 1994 might have a longer LOS than an infant with similar clinical risk prognosis born in 1996 due to advances in medical care, changes in intensive care criteria, or changes in reimbursement mechanisms. One hospital level variable was also included to correct for inherent differences between the two institutions not otherwise accounted for in the other predictor variables. Due to the suspicion that the effect of telemedicine may be modulated by birthweight, a single interaction term between telemedicine and birthweight was included. A spline with breakpoints at 500 and 1000 grams was used for birthweight.

Statistical Methods

The birthweight cutoff caused a very non-normal (negatively skewed) distribution of the data. Therefore, the natural log of LOS was used as the dependent variable. An ordinary least
squares (OLS) regression model was developed which used the independent variables described above to predict the natural log of the NICU LOS. All hypothesis tests and p-values reported are two-tailed. The STATA statistical package was used to generate all reported statistics.

RESULTS

There were a total of n=381 singleton infants with recorded birthweight less than 1500 grams surviving until appropriate discharge from intensive care. However, several infants had to be dropped from the study for one of the following reasons: 1/ a recorded birthweight of zero (therefore it could not be determined if they were subjects in the study); 2/ Data for 41 infants was not present in or derivable from the database, or 3/ data was not available from the institution to which the infant was transferred. Approximately equal numbers were dropped from both institutions.

Of the remaining 314 infants 177 were admitted to NHRMC and 137 to MMH. Of these VLBW infants, 75 were born at NHRMC after the telecardiology system. The characteristics of this group are summarized in Table 1. The infants born at NHRMC were of lower average birthweight, were less likely to be white, and more often female, when compared to those born at MMH. The mean birthweight of all infants in the study was 1082 grams, or approximately 2 pounds, 5 ounces. The average NICU LOS for all infants in the study was 54.8 days, indicating the severity of illness prevalent in this population.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>MMH</th>
<th>NH-pre*</th>
<th>Tmed**</th>
</tr>
</thead>
<tbody>
<tr>
<td>Admissions (n)</td>
<td>137</td>
<td>75</td>
<td>102</td>
</tr>
<tr>
<td>Mean brhwt. (g)</td>
<td>1109</td>
<td>1059</td>
<td>1064</td>
</tr>
<tr>
<td>Gender (% male)</td>
<td>59.8</td>
<td>61.3</td>
<td>40.2</td>
</tr>
<tr>
<td>Race, (% white)</td>
<td>79.6</td>
<td>50.7</td>
<td>45.1</td>
</tr>
</tbody>
</table>

* Infants admitted to NHRMC before Tmed
** The infants in the telemedicine group

Two variables were dropped from the model. Gestational age was dropped due to its high multicollinearity (r > 0.6) with birthweight. Method of delivery was dropped from the model due to mostly missing data (approximately 60% of the observations were not recorded). After these changes were made, the predictive power of the model was fairly high for neonatal studies; the adjusted R² value for the model was 0.51.

Several tests were performed to verify that the data meet the assumptions of OLS regression. The data were examined for serial autocorrelation and heteroscedasticity. The Durbin-Watson statistic was 1.77, putting it near the middle of the indeterminate range (this range for the given sample size and number of predictor variables is dL = 1.68 and dU = 1.86). Adjustments for autocorrelation were not performed. The data were also tested for heteroscedasticity using Cook and Weisberg’s test. Heteroscedasticity was found to be present. Therefore, Huber robust standard errors were used to correct for the heteroscedasticity.

ANALYSIS

Birthweight, gender, race, respiratory therapy, and institution (whether an infant was admitted to NHRMC or MMH) were all highly statistically significant (p < 0.01). Maternal age, date of birth and whether an infant was inborn or outborn were not statistically significant. See Table 2 for complete statistical results. This sign convention is a positive coefficient acts to increase length of stay.

Table 2. Results of Regression Analysis

<table>
<thead>
<tr>
<th>Predictor Var.</th>
<th>sign</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Telemedicine</td>
<td>-</td>
<td>0.001</td>
</tr>
<tr>
<td>Birthwt*Tmed Interaction</td>
<td>+</td>
<td>0.009</td>
</tr>
<tr>
<td>Birthweight Spline:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0 – 500 grams</td>
<td>0</td>
<td>0.691</td>
</tr>
<tr>
<td>501 – 1000 grams</td>
<td>-</td>
<td>0.000</td>
</tr>
<tr>
<td>1001 – 1500 grams</td>
<td>-</td>
<td>0.000</td>
</tr>
<tr>
<td>Respiratory Therapy</td>
<td>+</td>
<td>0.000</td>
</tr>
<tr>
<td>Institution (NH)</td>
<td>+</td>
<td>0.000</td>
</tr>
<tr>
<td>Gender (male)</td>
<td>+</td>
<td>0.001</td>
</tr>
<tr>
<td>Race (White)</td>
<td>+</td>
<td>0.000</td>
</tr>
<tr>
<td>Mother’s age</td>
<td>0</td>
<td>0.657</td>
</tr>
<tr>
<td>Date of Birth</td>
<td>0</td>
<td>0.123</td>
</tr>
<tr>
<td>Inborn</td>
<td>0</td>
<td>0.403</td>
</tr>
<tr>
<td>Intercept</td>
<td>+</td>
<td>0.010</td>
</tr>
</tbody>
</table>

(Adjusted R² = 0.51)

The main and interaction effects of telemedicine must be considered together. The sign on the interaction coefficient indicates that it acts in opposition to telemedicine’s main effect and that these effects, taken together show that the
NICU LOS reduction is larger for the lower birthweight infants. The difference is statistically significant at the α = 0.05 level for infants below birthweight 960 grams. This represents approximately one-third of the population. For higher birthweight infants, the NICU LOS is not statistically different. The magnitude of the predicted difference given the makeup of the telemedicine cohort is approximately 12.5 days per infant, or 17%.

Figure 1. Birthweight vs. NICU LOS

DISCUSSION

This study provides evidence which associates the adoption and utilization of a telemedicine system with a reduction in morbidity of VLBW newborn infants. While these findings are in line with the results of a previous study, which associated telemedicine with a reduction in the risk-adjusted NICU LOS of 8.6 days for low birthweight infants who underwent echocardiography, they should be interpreted with caution. There are many well-known hazards of using LOS as an outcome measure. In practice, the appropriateness of discharge from intensive care is not completely objective.

One of the difficulties in measuring intensive care LOS, particularly across institutions is distinguishing the difference between intensive and intermediate care. The criteria for determination of when an infant weighs enough or is stable enough to be discharged to intermediate care may be the primary reason for the difference in NICU LOS observed between the two institutions. While the experimental design and statistical methods used in this study dealt with the possibility of decreasing LOS over time, others may not be adequately accounted for. The two most significant of these may be insurance status and bed availability. A particular infant’s NICU LOS may have been inflated if the infant was stable enough for discharge to the general nursery but no beds were available, for example.

Additionally, there are many other outcome measures and quality of care issues, and other reasons different organizations may have for implementing telemedicine. All health care organizations strive to improve patient care and patient satisfaction. Hospitals without subspecialists desire to keep patients locally who might otherwise be transferred. Academic medical centers and large urban hospitals may employ telemedicine as a tool to build relationships and compete for patient referrals. Unpublished data evaluating the transport destination pre- vs. post-telemedicine shows a statistically significant increase in percentage of referrals to UNC.

The telemedicine system described in this article has been an effective method for reducing the turn-around time of neonatal echocardiogram interpretation. This is a critical parameter in decisions concerning whether or not to transfer an infant. Finally, these results are not necessarily generalizable to higher birthweight infants, who comprise the vast majority of the newborn population.

The need for sound comparative evaluations of telemedicine is widely recognized. These results indicate an association between the adoption of telemedicine and a reduction in NICU LOS for these infants. The reduction in NICU LOS is greater for lower birthweight infants, and the model predicts infants weighing 960 grams or less will have a statistically shorter stay. For infants between 960 and 1500 grams, the difference is not significant. The neonatologists and pediatric cardiologists involved believe that this reduction is due to more effective management of patent ductus arteriosus (PDA) and larger body of experience the subspecialists at the academic medical centers have in caring for the complications of extreme prematurity. An increase in use of lung surfactant and PDA ligations has been observed.

Given the observed difference in length of stay, average charges of approximately $2,400 per day for neonatal intensive care, and the characteristics of the telemedicine cohort, the net change in hospital expenditures on telemedicine can be estimated. This calculation produces an estimated reduction in charges of $2,900,000 at NHRMC over the one-and-a-half year treatment...
period. The potential savings if this were generalized to the 3 remaining NICUs in North Carolina that did not have cardiology support would be significantly greater.

CONCLUSIONS

Advances in neonatal care have dramatically improved the survival rates of premature infants. However, this improvement comes with a substantial economic cost at a time when the healthcare dollar is being more closely scrutinized than ever. Therefore, studies of interventions that may decrease the cost of neonatal intensive care are necessary.

Most previous studies of telemedicine have been limited by very small sample sizes[11]. Many barriers to telemedicine are cited, but the largest actual barrier may be the paucity of studies demonstrating adequate benefits[12]. In order for telemedicine to be embraced by the clinical community, scientific evidence demonstrating safety and efficacy must be presented. In order for the payor community to be willing support telemedicine, studies must demonstrate its cost-effectiveness with valid health economic data.

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References


Address for correspondence

The author may be contacted at:
UNC School of Public Health/HPAA
1101 McGavaran-Greenberg
Chapel Hill, NC 27599-7400

Email: jedi@unc.edu

WWW: http://telemmed.med.unc.edu/