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Cost analysis of neonatal tele-homecare for preterm infants compared to hospital-based care

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Abstract

Introduction: Neonatal homecare (NH) can be used to provide parents the opportunity of bringing cardiopulmonary-stable preterm infants home for tube feeding and the establishment of breastfeeding supported by neonatal nurses visiting the home. However, home visits can be challenging for hospitals covering large regions, and, therefore, regular neonatal hospital care has remained the first choice in Denmark. As an alternative to home visits, telehealth may be used to deliver NH. Thus, neonatal tele-homecare (NTH) was developed. Positive infant outcomes and the optimization of family-centred care have been described, but the costs of telehealth in the context of NH remain unknown. This study aims to assess the costs of NTH compared to regular neonatal hospital care, from the health service perspective.

Methods: The cost analysis was based on an observational study of NTH in Denmark (run from November 2015 to December 2016) and followed the Consolidated Health Economic Evaluation Reporting Standards. The intervention group were the families of preterm infants receiving NTH ($n = 96$). The control group comprised a historic cohort of families with preterm infants, receiving standard care in the neonatal intensive care unit (NICU) ($n = 278$). NTH infants and the historical group were categorized according to gestational age at birth at/under and over 32 weeks. The outcomes were NTH resource utilization, in-NICU hospital bed days, re-admissions and total costs on average per infant. The time horizon was from birth to discharge.

Results: The costs of NTH resource utilization were, on average, €695 per infant, and the total costs per infant, on average, were €12,200 and €4200 for infants at/under and over 32 weeks, respectively. The corresponding costs of the control group were €14,300 and €4400. The difference in total costs showed statistical significance for the group of infants under 32 weeks ($p < 0.001$).

Discussion: The cost analysis showed that NTH was less costly compared to regular hospital care, especially for infants born with gestational age at/under 32 weeks. NTH is an appropriate model of care for preterm infants and their families, is clinically effective and less expensive than similar services delivered in the hospital.

Keywords

Cost analysis, health economics, telehealth, home telecare

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Introduction

Preterm infants are fragile in the beginning of life and need specialized treatment and care in a neonatal intensive care unit (NICU). For cardiopulmonary-stable preterm infants, the priorities before discharge from the NICU are nutrition and infant growth, as well as weaning the infant from tube feeding to full oral feeding from the breast or bottle.[1,2] Neonatal homecare (NH) is commonly used in clinical practice[3,4] as an approach to optimize the conditions for the families during the weeks of transition from tube feeding to oral feeding. NH implies that parents manage tube feeding and breast- or bottle feeding establishment at home with support from a neonatal nurse visiting the home to monitor infant growth, oral feeding status and family well-being. Studies have shown high parental satisfaction with NH[2,4–6] and that NH may increase breastfeeding rates.[7,8] However, providing home visits can be expensive and time consuming for NICUs covering large regions. Therefore, telehealth has been introduced in NH, in the form of Neonatal Telehomecare (NTH), instead of home visits resulting in positive parental experiences, infant growth and breastfeeding rates.[9–11] The telehealth service used during NTH was designed beforehand using a participatory design approach, involving clinicians and parents.[11,12] During NTH, two weekly videoconferences between the parents in the home and a nurse in the NICU were conducted. Further, the telehealth service provided information on infant care, nutrition and family life with a preterm infant. Recent findings in the literature demonstrate that NTH is clinically feasible and accepted by parents,[10,13–15] but little is known about the costs of providing NTH compared to usual hospital care. Our study reports a cost analysis where the main outcome was to determine the total average costs of hospital care per preterm infant.

Methods

Study design

This analysis followed the Consolidated Health Economic Evaluation Reporting Standards statement[16] to ensure transparency of results. The economic analysis relied on data from an observational study conducted with a clinical purpose; hence, costs were estimated retrospectively. The analysis was conducted with a hospital-sector perspective, including direct healthcare resources and costs of equipment and software, and was conducted in accordance with methods for economic evaluation of healthcare programmes.[17]

NTH

The study was conducted in the NICU at Hans Christian Andersen Children's Hospital (HCA), Odense University Hospital in Denmark.[9,12] The telehealth service, an app developed for NTH (My Hospital app, Medware, Denmark), had options for videoconferences and chat messages between the NICU nurses and parents. Further, the nurses monitored infant growth by the growth data parents entered in the app connected to the infants' medical records in the NICU. Parents lent an iPad (Apple iPad Air 2, 16 GB), for communication through the NTH app, an electronic weighing scale (Seca© 376) and devices for infant care such as disposable bottles for expressed breast milk. At least twice a week, a videoconference between a nurse and at least one parent was conducted. Infants were discharged from NTH when they no longer required tube feeding and presented weight gain by solely oral feedings. The infants had planned check-ups in the NICUs during the NTH period. NTH services were delivered since November 2015.

Participants

The intervention group consisted of preterm infants and their parents who met the inclusion criteria (gestational age (GA) at birth $<37+0$ weeks, weight $\geq$1500 g, Post Menstrual Age $\geq$34 weeks, tube fed (exclusive/partially) and expected tube feeding for at least seven days, cardiopulmonary stable, parents able to collaborate with clinicians and use their guidance, and one parent must be speaking Danish). Historical control groups of preterm infants previously treated in the NICU were used for comparison. Infants in the historical control groups were enrolled in a national study of breastfeeding in the Danish NICUs conducted in 2009–2010[18,19] and very preterm infants (GA 24–32 weeks) participating in a randomized controlled trial (RCT) investigating nutrition, growth and allergic diseases among very preterm infants after hospital discharge conducted in 2004–2008.[20] These data was used, despite the long time period, since average length of stay has not changed significantly in the last 10 years (mean 18.4 days, standard deviation (SD) 1.4).[21] The infants in the control groups remained in the NICU until they no longer required tube feeding and presented weight gain on solely oral feeding.

Study size

The size of the sample represented in the study was derived from the number of infants that was eligible for NTH and accepted to participate in the study period.

Outcome measures

The outcomes of interest for the cost analysis of NTH were:

- NTH resource utilization
- In-NICU hospital bed days from birth to discharge
- Re-admissions
- Total costs on average per infant

NTH resource utilization

The number of videoconferences and check-ups in the NICU were documented by the nurses. They also registered the length of telephone calls during a two-month period. The use of functionalities in the app was monitored by the IT company that developed the telehealth service, using a code for usage tracking.

In-NICU bed days

Date registrations were used to determine the number of in-NICU bed days for each infant. For the control group, bed days were determined as *Date of birth until date of discharge from NICU*. For the intervention group, bed days were adjusted with an additional variable of *Date of NTH start*. Hence, we found bed days for the intervention group by *Date of birth until date of NTH start* and days spent on NTH by *Date of NTH start until date of NTH discharge*. No beds were closed during the NTH study.

Re-admissions

Each re-admission in the study period was registered by the project group.

Total costs

Total costs were measured as the average cost per infant comprising the costs of investments, the intervention and of hospital utilization. Data on software and equipment expenses were gathered from the project group. Investments were included in the measurement of costs, by adding the costs of developing the app, weighing scales, iPads, iPad holders and education of NTH nurses. The app and iPads were assumed to last for a period of three years and the weighing scales for 10 years. These are the standard expected lifespans. The programme-specific education of nurses was set to last for three years, assuming that no nurses left within this period. To estimate a cost per patient in this study, investment costs were annuitized and divided by number of patients in a year based on the study population ($n = 96$).

Intervention costs comprised the sum of time used by nurses per patient multiplied with the average hourly salary for a nurse in Denmark. This included time used for training parents for NTH and introduction to the telehealth service. In-NICU bed days, check-ups and re-admissions were multiplied by the associated standard 2016 Diagnose related Groups (DRG) tariff. DRG tariffs are used in the Danish Reimbursement system, and are fixed to reflect the average national costs for services in the hospital sector.[22] Costs were obtained in 2016 DKK prices and converted to euros (€100 = DKK745),[23] and no discount rates were applied. The time horizon of the analysis was the period from birth to discharge.

Sensitivity analysis

In accordance with Drummond et al.,[17] the estimation of costs was varied in three scenarios in a sensitivity analysis. Recently, a scoping review by Kidholm and Kristensen[24] showed that costs of equipment and software constitute a substantial share of total costs in economic evaluations of telehealth. The studies in the review used different methods for distributing investment costs, showing lack of consensus in this field on how to assess investment costs per patient. Therefore, the sensitivity analysis depicted three different methods of analysing costs of the NTH app (see the following scenarios 1–3) and the resulting impact on total costs:

- Scenario 1 (base case in this study): the most common is the equivalent annual cost method,[17] where investments are divided into expressing costs on an annual basis for the 96 preterm infants within the study; hence, it is assumed that the sample size per year is representative in the lifespan of the products.
- Scenario 2: a potential for expanding the patient group to a national level is used. Hence, investment costs of the app are divided into the number of potential patients in the area of uptake. Annually, approximately 4000 preterm infants receive treatment and care in a NICU in Denmark.[25]
- Scenario 3: assumes that investments can be seen as a one-time payment not related to running the intervention. Thereby, investment costs of the app are detached from the total costs per patient.

Statistical analysis

Data were analysed using R version 3.4.3 R Development Core Team (2008). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. ISBN 3-900051-07-0, URL http://www.R-project.org

For resource use, continuous variables presenting normal distribution were presented with mean and

SD. Variables with a non-normal distribution are presented with median, minimum and maximum values. The effects on in-hospital days were analysed with Quasi Poisson regression for count variables, adjusted for potential confounders as birthweight, GA and gender. Costing data were not all analysed by statistical tests, as they were not all available at the individual level. Total costs were analysed with logarithmic regression, adjusted for birthweight, GA and gender.

The analysis was performed and presented in two GA groups of the infants due to expected long and short admission to the NICU:

- Long: infants born with a GA $\leq 32+0$ weeks
- Short: infants born with a GA $> 32+0$ weeks

The two NTH groups were then compared to the two corresponding historical control groups.

Ethics

The NTH study was approved by the Danish Data Protection Agency (2008-58-0035) and approved by the management at HCA.

Results

A total of 96 preterm infants were enrolled in NTH during the inclusion period (November 2015–December 2016). Twenty-seven (28%) of the included infants were born with a GA $\leq 32+0$ weeks. The control group comprised 278 preterm infants, where 175 (63%) of them were born with a GA $\leq 32+0$ weeks. The clinical study reported no statistically significant differences at baseline between the two groups for infants with GA $> 32+0$ weeks.[9] However, infants in the NTH group were younger at birth and presented slightly lower birth weight for age z-scores compared to historical controls. In the group of infants with GA $\leq 32+0$ weeks, no statistically significant difference between groups was present.[9]

The central unit prices were app costs of €18,200, videoconference costs of €34, hospital check-up costs of €175 and a bed day cost of €270 (Table 1).

For infants with GA $> 32+0$ weeks, average length of NTH enrolment was around 17 days per infant (Table 2). For the group with GA $\leq 32+0$ weeks, the corresponding estimate was 29 days. In the intervention period, infants with GA $\leq 32+0$ weeks had six videoconferences on average, and those with GA $> 32+0$ weeks had three. Nurses wrote five chat messages on average per infant. Besides the use of the telehealth service, each infant had a number of planned check-ups in the NICU, four visits on average per infant with GA $\leq 32+0$ weeks and two for those with GA $\leq 32+0$ weeks.

Differences between groups for in-NICU bed days were statistically significant in both GA groups, adjusted for confounders ($p < 0.001$). A total of six infants were re-admitted during NTH, corresponding to less than 0.2 readmissions per infant on average in both GA groups.

The investments comprised €125 on average per patient for the application, iPad and specialized education of the NTH nurses (Table 3). Cost of the intervention was €998 per infant with GA $\leq 32+0$ weeks and

Table 1. Types of resources used and unit price.

Type	Description	Price per unit, €
Investments		
My Hospital app	Development of an app for NTH. Including service and maintenance. Expected lifespan three years	€18,201
Weight scale	Seca 376 weight scale. Expected lifespan 10 years	€810
iPad	Apple iPad Air 2 (16 GB). Expected lifespan three years	€511
IPad holder	Cover holders for iPads. Expected lifespan three years	€32
Education of personnel	Five hours of children first aid and growth course for nurses + two hours technical education (seven hours × nurse salary). Expected lifespan three years	€240
Intervention		
Introduction for families	Three hours of introduction for each family with nurse (three hours × nurse salary)	€103
Videoconference	One hour of videoconference with nurse (one hour × nurse salary)	€34
Hospital check-ups	DRG rate for an outpatient visit for children age 0–6 years (approx. one hour of nurse + physician, including tests and treatments)	€176
Chat message	Five minutes for each reply (0.08 hours × nurse salary)	€3
Resource utilization in hospital		
Readmission during NTH	Average DRG rate per readmission to the hospital during NTH	€1726
Bed day	In-hospital day at the NICU defined as DRG rate per. In-hospital day	€270

Table 2. Resource utilization, average per patient.

	Neonatal tele-homecare group ($n = 96$) ($\leq$32 weeks) ($n = 27$)	Historical control group ($n = 278$) ($\leq$32 weeks) ($n = 175$)	Neonatal tele-homecare group ($n = 96$) (>32 weeks) ($n = 69$)	Historical control group ($n = 278$) (>32 weeks) ($n = 103$)
Intervention				
Intro for families, mean	0.93	0	0.93	0
Video consultations, mean (SD)	5.6 (3.30)	0	3.38 (1.82)	0
Chat messages, mean	5.48	0	5.48	0
Outpatient visits, mean (SD)	3.96 (2.21)	2	2.03 (1.47)	0
Days on NTH, mean (SD)	28.97 (15.28)	0	16.76 (9.08)	0
Hospital resource utilization				
Bed days in NICU, mean (SD)*	39.96 (19.41)	51.78 (20.86)	12.78 (6.52)	16.19 (6.96)
Bed days in NICU, median (range)	36 (14–104)	47 (22–107)	10 (3–35)	16 (2–34)
Readmissions, mean (SD)	0.15 (0.36)	0	0.03 (0.17)	0

*P-value for bed days in NICU was <0.001 for $\leq$32 weeks and >32 weeks.

Table 3. Average cost per patient.

	Neonatal tele-homecare group ($n = 96$) ($\leq$32 weeks) ($n = 27$)	Historical control group ($n = 278$) ($\leq$32 weeks) ($n = 175$)		Neonatal tele-homecare group ($n = 69$) (>32 weeks) ($n = 69$)	Historical control group ($n = 278$) (>32 weeks) ($n = 103$)	
Investments						
IT infrastructure (app), mean	€82	0		€82	0	
Devices, mean	€39	0		€39	0	
Education, mean	€4	0		€4	0	
Intervention						
Intro for families, mean	€95			€95		
Video consultation, mean (SD)	€191 (113)	0		€116 (62)	0	
Chat messages, mean	€16			€16		
Outpatient visits, mean (SD)	€696 (388)	€351		€357 (257)	0	
Hospital costs			P-value			P-value
Bed days in NICU, mean (SD)	€10,793 (5246)	€13,983 (5636)	<0.001	€3,452 (1761)	€4,374 (1879)	<0.001
Readmissions, mean (SD)	€296 (775)	0		€34 (279)	0	
Total cost per patient on average, mean (SD)	€12,213 (5396)	€14,334 (5636)	<0.001	€4,188 (1883)	€4,374 (1879)	0.0847

€583 for infants with GA $> 32 + 0$ weeks. For infants with GA $> 32 + 0$ weeks, the average cost of bed days was €3452 and €34 for readmissions during their NTH period. The control group had corresponding costs of €4374. The estimate for infants with GA $\leq 32 + 0$ weeks was €10,793 for bed days and €296 for readmissions. The control group had corresponding costs of €13,983. The differences in both GA groups was statistically significant ($p < 0.001$). For infants with GA $> 32 + 0$ weeks, the NTH group had average total costs of €4188 and the control group €4374, which was statistically insignificant ($p = 0.0847$). The estimate for infants with GA $\leq 32 + 0$ weeks was €12,212 for the NTH group and €14,334 for the control group, and the difference was statistically significant ($p < 0.001$).

The average weighted total cost per infant was €6380 for the intervention group and €10,644 for the control group (Table 4). The sensitivity analysis resulted in a difference ranging from –€4264 to –€4389 depending on the scenario. Hence, analysing investment costs in different ways resulted in a

Table 4. Sensitivity analysis, average cost per patient (€).

	Neonatal tele-homecare group (I) Total costs	Historical control group (C) Total costs	Difference I–C	Neonatal tele-homecare group Investment costs
Scenario 1: base case Equivalent annual costs	6380	10,644	–4264	125
Scenario 2: national expansion scenario Cost/$n = 4000$	6300	10,644	–4344	45
Scenario 3: investments omitted as sunk costs	6255	10,644	–4389	0

difference of €125 per patient. In other words, when 100% of the investment costs were removed (from €125 to €0), it corresponded to a change of 2% in the total average costs per patient, and did not considerably affect the overall result.

Discussion

Total costs per patient, on average, depended on GA. For the GA $> 32+0$ group the total difference in costs were estimated to €200 favouring the NTH group, while in the GA $\leq 32+0$ group they were lower for the NTH group by €2100 on average, reaching statistical significance ($p < 0.001$). This was mainly because the use of bed days in NICU was higher for the control groups. When results were tested by regression analysis, it was observed that NTH infants had statistically significant shorter in-NICU stays ($p < 0.001$). The clinical study showed that the use of telehealth led to positive outcomes in terms of breastfeeding and infant growth, following discharge from the NICU.[9] It demonstrated that a higher proportion of preterm NTH infants were exclusively breastfed at discharge, statistically significant among singleton infants with GA $\leq 32+0$ weeks ($p = 0.03$). Furthermore, NTH facilitated a parental experience of family-centred care.[10] Anecdotally, clinical staff in the NICU had accepted the technology and workflows, according to interviews made by the project group. Their support of the new service and the ease of implementation are likely to be due to the participatory design process implemented in the early phase of the project.[26]

The study succeeded in creating a new organization around treatment and care for cardiopulmonary-stable preterm infants by involving telehealth in NH. Telehealth has recently been said to increase the costs of care for some technological solutions because of high costs of equipment.[24,27] On the other hand, studies in the area of chronic care have demonstrated cost savings because telehealth has reduced the use of other hospital-based services,[28–30] although most without statistical significance in costing estimates.[29,30] The diverse results suggest that a certain amount of attention must be paid to the costs of the telehealth service, as both equipment costs and salaries may increase the costs of home monitoring. However, this study identified that telehealth can be supplied without an increase in costs per patient. NTH is thereby not only advantageous for the families but also for the hospital because of the decrease in in-hospital bed days.

Since investment costs are often a substantial part of average cost per patient, the method of assessing investments might affect the result. By varying methods of assessment, this analysis showed a variation in costs per patient of €125, which is a 2% change in total costs. Therefore, changing the method of assessment did not change the conclusion. This study is an economic analysis with a hospital perspective that compares the costs of two competing treatments. The method differs from a business case for a specific hospital, which describes expenditures and impact on reimbursement with different risks and uncertainties.[31] In a business case, it would be essential to know how admissions are registered and reimbursed in the period of tele-homecare. The economic consequences at another hospital with fee-for-service would depend highly on the reimbursement from utilizing the capacity on beds.

Limitations

One limitation of this study was the low internal validity due to historical control groups, with older data and possible unadjusted confounding factors. This means that a range of factors, besides bed days, could be contributing to the lower costs in the NTH group. While a RCT design could strengthen internal validity, the observational study design made it possible to assess the effectiveness of the treatment in real-world circumstances. Interpretation of the results obtained from both RCTs and observational studies can help understand the efficacy/effectiveness and safety of a therapeutic option.[32] Another limitation was lack of complete individually recorded data on telephone

calls and chat messages for estimating variability in intervention costs. Since this was not possible due to very busy NICUs, recordings from the telehealth provider were considered adequate.

The generalizability of the findings may be limited due to the study being in one hospital only. The cost analysis reflected that the price of a bed day is estimated locally and without procedures or medication. Hence, findings may be applicable in settings with similar public healthcare systems, but prices should be estimated according to the specific context.

However, the practical implications of NTH were improved family-centred care, satisfactory clinical outcomes in infants and a successful implementation in the organization. NTH is continued as part of the treatment offered at the NICU in our hospital. This study is, to our knowledge, the first to assess the costs of NTH compared to hospital care. Future studies could benefit from larger populations and cost data at the individual level.

Conclusion

The costs of providing NTH for preterm infants and their parents were outweighed by a reduction in in-hospital days for the group of infants with $GA > 32+0$ weeks. The group of infants with $GA \leq 32+0$ weeks had lower costs on average compared to the control group, and the statistically significant difference in bed days between groups suggests that NTH may reduce in-hospital bed days. NTH is an appropriate model of care for preterm infants and their families, is clinically effective and is less expensive than similar services delivered in hospitals.

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