The Margins of Viability

F. McElligott[1], S. Kinsella[2] & R. K. Phillip[3]

Abstract

Background: Prematurity and extremely low birth-weight (ELBW) is a well recognised financial burden on health care in the developed world. Cost of treatment increases with decreasing gestation. While cost-benefit and cost-effectiveness analyses have been calculated and extrapolated (Gilbert *et al*, 2003, Payne *et al*, 2004), it is frequently the average and the median that is sought. An extremely high cost however is always possible at the beginning of each case, and in some, the eventuality. This study examines one such case of an infant conceived by in-vitro fertilisation (IVF), and attempts to determine the total cost from conception to discharge from the special care baby unit.

Aims:

1. To determine the precise total health care expenditure through capital and recurrent expenditure on an infant born at the margins of viability from birth to discharge from acute hospital care.
2. To accurately calculate the unit cost of care following birth at the margins of viability and subsequently the cost of care per week of a 24/40 gestation neonate.
3. To use the total and marginal cost calculated to create a pilot model for cost following the local delivery of a 24/40-week gestation infant.

Methods: We compiled a file of tests, treatments and interventions carried out on an ELBW infant. Unit costs were assigned. Appropriate values for professional input and in-patient non-medical consumables were calculated in per-unit per-day values and incorporated. Further direct costs incurred by the family were also included as well as proportional infrastructure, equipment, and refurbishment expenditures. Marginal Cost (MC) of daily treatment was measured as change in Total Cost (TC) per extra day of life. We determine total costs of treatment per extra week of life by linear regression ($R^2 = 0.71$, p-value < 0.05). The evolution of costs was then demonstrated in terms of cumulative percentage of weekly costs over time.

Results: The total cost was found to be €665,219.88. Our analysis shows that by increasing gestation cost could be decreased by €5,167.50 per week of increased gestation, with a fixed cost of €26,608.00. Total cost and marginal costs were found to be substantially larger from published observations in other countries, including the UK and USA (Payne *et al*, 2004, Phibbs *et al*, 2006, Petru *et al*, 2006). This is possibly due to the detailed nature of the data set.

Conclusion & Further Work: With the total and unit cost of our index case determined, a model of health care expenditure of an infant born locally is known. In further work we apply this model as a benchmark to a large dataset of infants born in the mid-western region of Ireland.

Keywords: *Health economics, cost measurement, pediatric intensive care economics*
JEL Codes: I11, I12.

[1] Senior House Officer in Pediatrics, Midwestern Regional Hospitals. Email: fionamcelligott@yahoo.co.uk.
[2] Junior Lecturer, Dept. Economics, Kemmy Business School, University of Limerick. Email: Stephen.Kinsella@ul.ie.
[3] Consultant Pediatrician & Neonatologist, Midwestern Regional Hospitals. Email: roykphillip@yahoo.co.uk.

1. Introduction

Prematurity and extremely-low-birth-weight (ELBW) is a well recognised financial burden on health care in the developed world (Petrou *et al*, (2006), Akman *et al*, (2002)), and cost increases with decreasing gestation (Gilbert *et al*, 2003, Phibbs *et al*, 2006). Despite an improvement in birthweight-specific survival rates, prematurity and extreme prematurity rates have remained constant over time (Phibbs *et al*, 2006). Consequently the financial expenditure has increased. At the beginning of each case, it is impossible to say which or how many complications the infant may suffer before discharge or in some cases death. While cost-benefit and cost-effectiveness analyses have been calculated and extrapolated (Doyle *et al*, 2004), frequently only the average and median costs are sought. An extremely high cost outcome, however is always possible at the beginning of each case, and in some cases, the eventuality.

The purpose of this study is to retrospectively examine in as detailed a manner as possible, the case of an infant born at twenty-four weeks and four days gestation. The patient was delivered by emergency caesarean section and weighed 525 grams. At the birth of the index case, Apgar scores were normal (9^1, 10^5, 10^{10}) and the infant was electively intubated at one minute of life. The patient was given 3 doses of surfactant, prophylactic ibuprofen, antibiotics and phototherapy according to local protocol and commenced on high-frequency oscillation ventilation (HFOV). The patient remained on HFOV for one month, and then continued to be dependent on Synchronized Intermittent Mandatory Ventilation (SIMV) until 111 days old.

The infant's clinical course included resuscitation at birth, prolonged antimicrobial therapy for clinical and microbial signs of sepsis, in addition to multiple blood product transfusions and transfer of the infant to national paediatric centres on four occasions; twice for suspected necrotising enterocolitis (NEC) which was treated conservatively with IV antibiotics, once for overwhelming sepsis and on the fourth occasion briefly for removal of Broviac® central venous access. As is the case with almost all ELBW babies, the patient was seen by a variety of specialties including radiology, haematology, ophthalmology, cardiology, plastics, general paediatric surgery, dietetics, physiotherapy, and speech and language therapy. Upon discharge home the patient was receiving vitamin and iron supplements, and was oxygen dependant.

This study aims to determine the precise total health care expenditure through capital and recurrent expenditure on the infant from birth to discharge home from acute hospital care, and to accurately calculate the unit cost of care and subsequently the cost of care per week. The total and marginal cost calculated will be used to create a pilot model for cost comparison, following the local delivery of a 24/40-week gestation infant.

This paper is laid out as follows: Section 2 describes the method of data collection and cost calculations employed. Section 3 describes the simple econometric framework we develop to describe the data. Section 4 discusses our results and points to further work.

2. Method

Consent for the study was obtained from the subject's parents and medical team. A data file was prepared of tests, treatments and interventions carried out as found in the medical notes, laboratory records, and pharmacy records. Unit costs were assigned. Appropriate values for professional input and in-patient non-medical consumables were calculated in per-unit, per-day values and incorporated. Further direct costs incurred by the family were also included, as well as proportional infrastructure, equipment, and refurbishment expenditures. Certain assumptions were made in instances where records were not kept, for example, frequency of replacing intravenous canulae, naso-gastric feeding tubes, and measuring blood glucose levels. It was also assumed that there was negligible waste of resources and disposable equipment during the period of study. These omissions would largely underestimate the economic cost of these events.

The calculation of economic cost begins with the choice of units. To create a cost measurement, daily records were compiled, collated and matched to unit costs for each procedure/product/specialty used. The highest possible resolution of the data was chosen—a daily costing of every recorded consultation and procedure applied to the patient.

Pharmacy and consumable equipment were assigned unit costs as per the relevant invoices. Laboratory tests were estimated as the sum of the reagents plus manpower—calculated as total lab payroll per year divided by total number of test carried out. Thus this did not take into account the cost of purchasing, running and maintenance of machines used. Ventilation equipment running costs were calculated by the electricity running costs per day of use and included the cost of purchase and maintenance. Current refurbishment costs for the unit were known and were allocated to per-bed-day values. Reviews by specialist teams were allocated private consultation charges, as were radiological investigations. Full access to the data including individual entries and their sources is available from the corresponding author by request.

2. 1 Cost calculation methodology

Unit (direct) costs were gathered from appropriate sources and multiplied by the number of usages of that product or service. The total cost was then split into daily amounts and differenced by one day to provide a measure of the marginal cost of one day of extra life for the infant. Formally we solve for the daily change in total cost, divided by the increasing quantity of life (in this case one extra day), via

where *TC* is total cost, *Q* is extra days of life (indexed here at 1), and *MC* is marginal cost calculated in 2006 Euros. The absolute value was taken in each case to remove negative values.

Total costs were defined as the sum over the series of variable costs and fixed costs. Examples of fixed costs were the ICU direct cost per patient per bed, the pharmacy pay cost per day and the RMH cost per bed day. Examples of variable costs were the specialty reviews (Haematology, Surgical, Cardiac, Ophthalmic, etc) and drugs and procedures administered under doctor's orders and at their discretion (Fluconazole, Ampicillin, Mycostatin, Ibuprofen, etc).

Variable costs tended to change as the patient's condition changed. The cost of a neonatal bed per day remained the same regardless. We calculate the cost per bed day as follows: direct non-pay cost per day (bed, depreciation costs included, machine maintenance) plus direct pay costs (nursing staff, attendants, not including medical pay) plus overhead costs (refurbishment, admin, travel and equipment, cleaning, security, taxi costs) plus medical pay costs (consultant and non consultant medical staff). Per week, this works out at an average of €21458.71.

The total cost was found to be €665,219.88. Our analysis shows that by increasing gestation cost could be decreased by €5,167.50 per week of increased gestation, with a fixed cost of €26,608. Total cost and marginal costs were found to be substantially larger from published observations in other countries, including the UK and USA (Payne *et al*, 2004, Phibbs *et al*, 2006, Petrou *et al*, 2006).

We calculate the variable cost as follows: every procedure, drug administered or test run on the patient on each day is associated with a unit cost, and summed per day. We now turn to the analysis of the data gathered.

3. Data Analysis

Marginal Cost (MC) of daily treatment was measured as change in Total Cost (TC) per extra day of life. Total cost of treatment per extra week of life was determined by generalised least squares. The evolution of costs was then demonstrated in terms of cumulative percentage of weekly costs over time. Cost over time was also related to the infant's weight.

Marginal cost is shown in Figure 4 on page 9. The figure pulls out the influence of the medical events on the patient and their associated (daily) cost. For example, on day 17, the patient had fungal sepsis, had red cell tranfusions, platelet transfusions, an emergency transfer to Our Lady's Hospital for Sick Children, Crumlin. The patient was seen by surgical and cardiac teams upon arrival. Each of these cost 'events' is captured in our total cost measure, summarised in Figure 3.

Total cost was seen to decrease almost linearly with each extra week of life. Figure 1 below plots a fitted scatterplot of total cost per week during admission. We fit a generalised least squares model to this data for the regression line $y = -51.675x + 26608$. Here y = total cost and x is weeks of life. We can see that the fixed cost of maintaining the patient in the acute hospital setting dominates the overall cost of care.

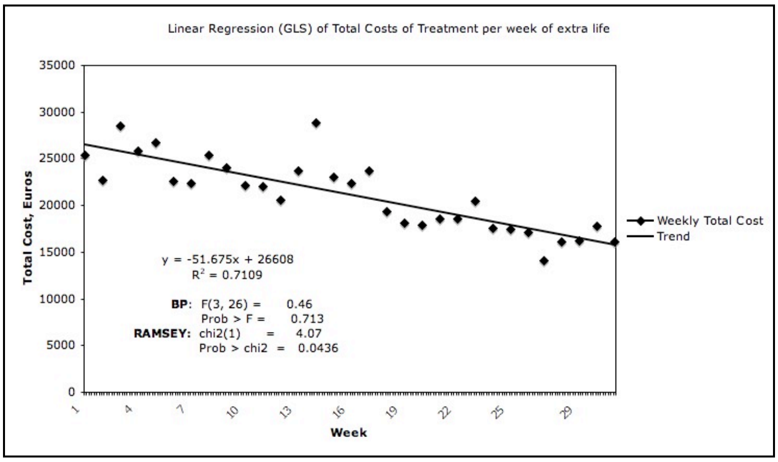

Figure 1: Regression of Total Costs of Treatment.

3.1 Regression Diagnostics

Regression diagnostics yielded the following results for the data. We tested for heteroskedasticity using Breusch-Pagan, (p-value > 0.713), misspecification and omitted variables (Ramsey $\chi^2 p = 0.0436$), along with a Durbin Watson test (d-stat (2, 31) = 1.6) and Akaike and Bayesian Information Criteria

(570.53, 503.70, respectively). Thus we can say that there probably is some omitted variable bias, and there is positive autocorrelation of the error terms, but this is largely to be expected given the context of the study. The overall relationship tallies with our expected results. Plotting the fitted residuals with a 95% confidence interval to the independent variable, as we do in Figure 3, reveals the (expected) autocorrelated nature of the data.

Figure 2: Residuals plotted to Independent variables.

We calculate total cumulative cost per week of inpatient stay in figure 4 below. The basic message of this is that though variable costs did have an impact on the overall cost of stay, the fixed costs defined above in fact contributed the largest proportion.

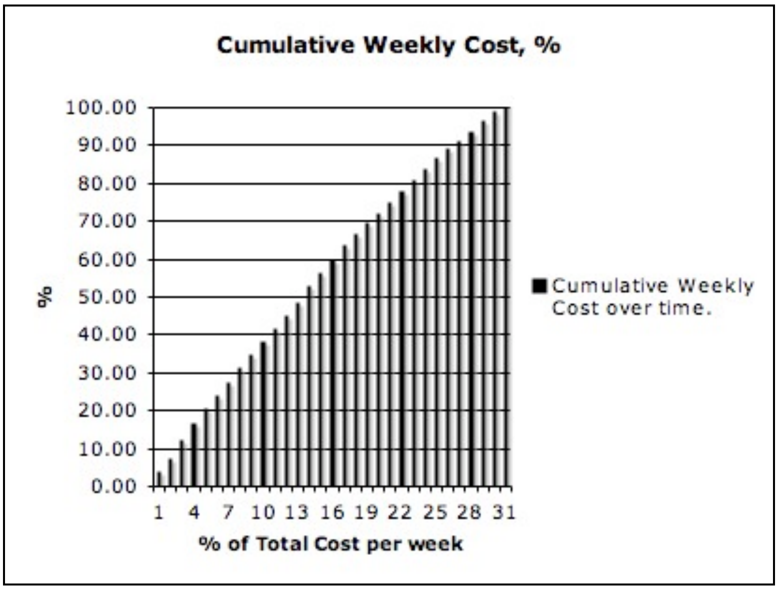

Figure 3: Cumulative Cost over time, %.

4. Discussion

The analysis provides an account of the precise total health care expenditure on an infant born at 24 weeks gestation and presents a model on which projected expense on future extremely preterm infants can be based. The detailed nature of the data set allows for costs calculated to be tailored to other individual cases where specific interventional procedures are performed.

Per-bed day costs were not calculated specifically for the neonatal intensive care unit, rather they were derived for the maternity hospital as a whole including antenatal, postnatal and labour ward. In this respect it is possible that they underestimate the true running cost. In order to correct for this per-bed day costs for the adult intensive care unit in the region were used to adjust for higher nurse-to-patient ratios and non-medical consumable costs.

Despite some limitations, this study provides an estimation of cost that may be used in critical care making decisions. This is unlikely ever to be the single deciding factor in such cases, but the influence of cost on patient is sure to become more important in the Irish health care setting as increased efficiency becomes a priority.

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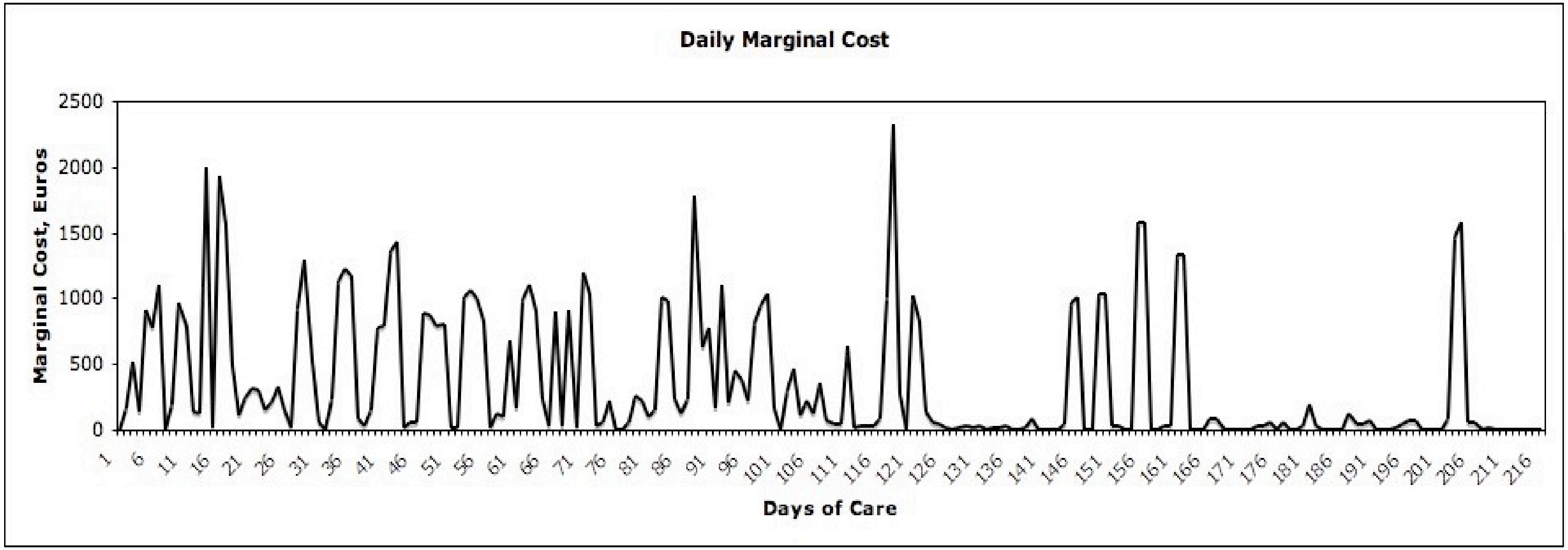

Figure 4. Daily Marginal Cost over 212 days of care. (€/day)