Margins of viability: value of microcosting and a model for intensive care economics.

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Abstract

Background: Prematurity and extremely low birth-weight (ELBW) is a well crecognised financial burden on health care in the developed world. In general 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 the cost of care one such case of an extremely low birth weight (ELBW) infant.

Aims:

1. To determine as accurately as possible, the total health care expenditure through capital and recurrent expenditure on an infant born at the margins of viability from admission to discharge from acute hospital care.
2. To calculate the unit cost of care following birth at the margins of viability and subsequently the potential upper limit of cost of care per week of a 24/40 gestation neonate.

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 determined the total costs of treatment per extra week of life by regression (R^2 = 0.741, 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 €611,497,38. Our analysis showed that by increasing gestation the cost could be decreased by €8531.00 per week of increased gestation, with a fixed cost of €28,755.00. 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) perhaps reflecting the detailed nature of the data set, in addition to our case being an extremely sick infant and hence a statistical out-lier. This infant's illness severity and number of complications warranted a high level of service provision. There are differences in cost calculations as well, given the differing nature of health care and delivery system in Ireland with the public-private-partnership model.

Conclusion: Our observations would support ring-fencing neonatal intensive care funding nationally, which will enhance local cost containment measures as well as

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intensive care fund allocation and tracking through the provision of extra funding for centres which experience comparable high cost healthcare events. Our observations further emphasize the value of local microcosting especially for 'intensive care economics'.

– Keywords: *Health economics, cost measurement, microcosting, intensive care economics, ELBW infant.*

1. Introduction

Prematurity and extremely-low-birth-weight (ELBW) is a well recognised financial burden on health care in the developed world (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 on ELBW infants 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. There is a high degree of uncertainty with regard to cost of care, which is why the examination of an extreme outlier has value in this setting. 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 24 weeks and four days gestation, who's postnatal course was complicated even considering her gestational age. The patient was delivered by emergency caesarean section and weighed 525 grams. This study aims to determine the precise total health care expenditure through capital and recurrent expenditure on the infant from admission 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 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 on both occasions 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 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 teams and hospital management. 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 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, and valued at 2006 euros. 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. In keeping with local practice, the infant's ventilation was not overseen by a respiratory therapist, consequently no such cost was incurred. 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[5].

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. It is highly likely therefore

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[5] Full access to the data including individual entries and their sources is available from the corresponding author by request.

that they underestimate the true running cost. In order to correct for this per-bed day costs for the local adult intensive care unit were used to adjust for higher nurse-to-patient ratios and non-medical consumable costs.

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 of life). 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 intensive care unit (ICU) direct cost per patient per bed, the pharmacy pay cost per day and the Regional Maternity Hospital cost per bed day. Examples of variable costs were the specialty reviews (Haematology, Surgical, Cardiac, Ophthalmology, etc) and drugs and procedures administered under doctor's orders and at their discretion (Fluconazole, Ampicillin, Mycostatin, Ibuprofen, etc).

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.

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).

Nursing assignment is highly correlated with patient acuity and overall treatment intensity. Most extremely preterm infants drop down to an assignment of 2 babies to 1 nurse within a few days after birth, with this ratio returning to 1:1 only when complications arise. In the case we study, however, the infant required a 1:1 nurse until day 125 of life, which is very unusual. After this period, the infant stepped down to a 1:2 infant to nurse ratio for 20 days, but then went back up to 1:1 for 19 days due to complications. Thereafter, the infant went to a high-dependency growing nursery within the special care baby unit, where infant to nurse ratio was 1:4. Our study costs this change in treatment intensity appropriately.

The total cost was found to be €611,497.38. Our analysis, detailed in section 3, shows that by increasing gestation, cost could be decreased by €8531.00 per week of increased gestation, with a fixed cost of €28,755. 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). Since we are dealing with a different health care structure in Ireland, all our estimates should be taken in that context. The most comparable paper to our study, Phibbs et al (2006), report a cost of $600,000 (2003) US dollars for a 95th percentile infant, born at 24 weeks' gestation in the United States, who survived. The US health system has different elements driving costs, most notably labour, and thus the differences in our studies may be explained.

We now turn to the analysis of the data gathered.

3. Data Analysis

The daily change in the cost 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 daily cost changes are shown in Figure 1. 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 (note 1 in the figure). The patient was seen by surgical and cardiac teams upon arrival. The total cost of care for the patient on that day spiked because of the various procedures being performed, and that increased in activity is captured fully and on a daily basis in figure 1. On day 117 (see note 2 in figure 1), patient was transferred by ambulance from Our Lady's Hospital for Sick Children to the Regional Maternity hospital in Limerick having had a central line insertion. Similarly, day 202 (see note 3 in figure 1), with the patient's costs of daily care declining as full term was reached, saw the patient receive a respiratory synctial virus prophylaxis with Palivizumab, and the figure displays this intervention in cost terms also.

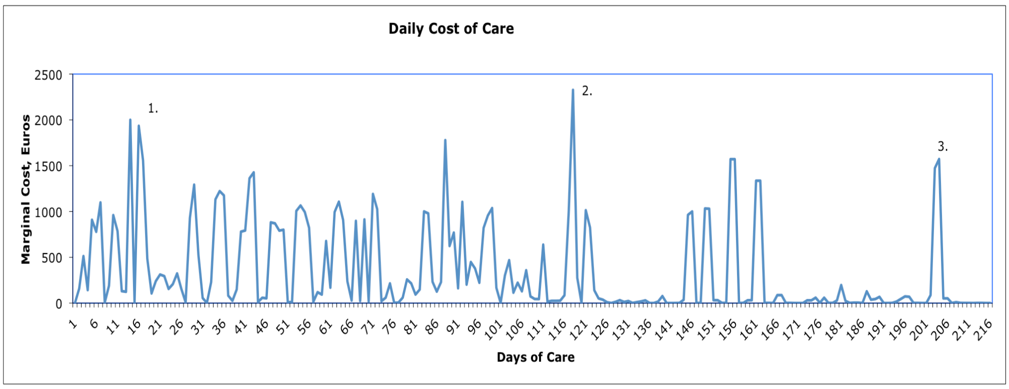

Figure 1 Daily costs per day of life from birth to discharge over 216 days of care.

***Note 1*: Day 17. Patient had fungal sepsis, had red cell tranfusions, platelet transfusions, an emergency transfer to Our Lady's Hospital for Sick Children, Crumlin. *Note 2:* Day 117. Patient transferred by ambulance from Our Lady's Hospital for Sick Children to the Regional**

Maternity hospital in Limerick following a central line insertion. ***Note 3*****: Day 202. Patient receives respiratory synctial virus prophylaxis with Palivizumab.**

Total cost was seen to decrease almost linearly with each extra week of life, in line with Schreogg (2008) and Hollingsworth (2008). Figure 2 plots a fitted scatterplot of total cost per week during admission. All defined variables, as well as the interactions of variables, were tested within the model in a general-to-specific approach (Hendry, 1995) whereby the least significant variables were eliminated, while keeping COST as the only higher-level variable. We fit a generalised least squares model to this data for the regression line such that *WEEKLY EXTRA COST = -85.31 (WEEKS) + 28755*. We fit polynomial, exponential and weighted least squares to the data, but none produced a better fit commensurate with a better interpretation of the data, so we opted for the simplest fitting procedure[6]. We are of course aware that this regression is based on data obtained from one individual and thus the power of this series of tests will perforce be low. However, as discussed above, this patient is an outlier, both in terms of cost of care and in terms of health care outcomes: the patient survived by an unusually high cost treatment pathway, and is neuro-developmentally age-appropriate. This patient spans the range of cost and health outcomes possible, and for that reason we include a detailed weekly breakdown of the costs of care of this patient as a limiting case with appropriate caveats.

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[6] Regression diagnostics yielded the following results for the data. We tested for heteroskedasticity using the Breusch-Pagan test, (p-value > 0.713), misspecification and omitted variables using Ramsey's RESET test, along with Durbin Watson h tests (h-stat(2, 31) = 1.6) and Akaike and Bayesian Information Criteria tests (570.53, 503.70, respectively). All tests clearly pointed to a parsimonious identification of this model, with the caveat that some auto correlation is present, as one would expect.

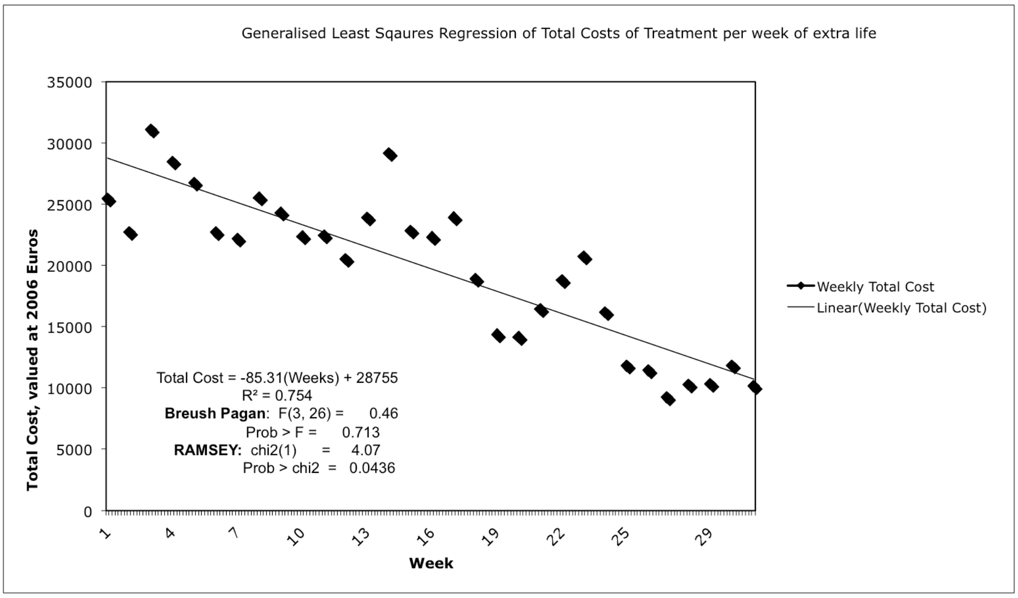

Figure 3: Regression of Total Costs of Treatment.

4. Discussion

Our analysis provides a detailed retrospective account of the precise total health care expenditure on an infant born at 24 weeks gestation. While the study carries the limitations of a retrospective case review, this aids to reduce bias which could have ensued with prospective monitoring of resource consumption.

The authors recognise and appreciate this is an extreme case. This infant, in cost terms, was an outlier, a highly costly healthcare event. We feel it is important to study these occurences in detail, because understanding the cost implications of extremely preterm infants allows us to plan more effectively for their eventuality. To take a hypothetical example, if we knew there were 100,000 babies born in Ireland, and 100 of these were premature, with 20 born at less than 26 weeks gestation, 3 might have the same cost profile as the case we study. Ringfencing funds nationally to take account of the high cost nature of such cases allows local cost containment measures to take their full effect, while helping local centres cope with the burden of these extreme cases. The policy implication of our study is a budgeting change, where funds are secured nationally and allocated locally as the need arises. We would advocate such a measure.

Total cost and marginal costs were found to be notably different from published observations in other countries including the UK and USA. There are differences in cost calculations, given the differing nature of health care systems both in the UK and USA. This observation further emphasizes the value of local microcosting.

Decisions involving the care of extremely preterm infants often result from strongly held beliefs rather than evidence (Modi 2008).

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