Original Article

Cost-Effectiveness Analysis of Malaysian Neonatal Intensive Care Units

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OBJECTIVE:

To perform a cost-effective analysis on the care of infants between 1000 and 1500 g birthweight (the study group), where outcomes are measured as survival to 1 year of age.

METHODOLOGY:

This was a multicenter observational study to determine the outcome, cost and cost-effectiveness of neonatal intensive care provided by Ministry of Health (MOH) Pediatric services. A total of 333 patients enrolled were eligible for analysis according to the inclusion and exclusion criteria of this study.

RESULTS:

Overall survival probability of the study group infants at 1 year of age was 78%. Survival at 1-year of age was 77% for infants with birth weight 1000 to 1249 g, 79% for 1250 to 1499 g. Survival at 1 year of age for the sample group was 53% for 22 to 27 weeks gestation, 80% for 28 to 36 weeks. The average cost-effectiveness ratio (CER) of neonatal intensive care for the study group infants was US$26 per survivor at 1 year of age (95% confidence interval US$3411, 5160).

CONCLUSION:

There was variability in the outcome and cost-effectiveness between the neonatal units, which need to be further assessed. However, neonatal intensive care services provided for the study group infants were cost-effective compared to that in developed countries.
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INTRODUCTION

Evaluation of a public health service includes determining its effectiveness (outcome assessment), efficiency (economic evaluation), accessibility (reachability of services) and equity (equal provision for equal needs).[1,2] All agree that rigorous evaluation should be an integral component of a service operation, though this is rarely performed in practice.

Neonatal care service in Malaysia is almost entirely publicly funded and has expanded substantially over the last 20 years. Perinatal and neonatal outcomes have also improved considerably in the same period. Prior to 1995, the perinatal mortality rates (PMR) ranged from 12.6 to 25.4 per 1000 births depending on the hospital and region served. The PMR has since dropped to 9.7 per 1000 births in 1999.[3] Similarly, the neonatal mortality rate has shown a gradual decline from 14.2 per 1000 livebirths (LB) in 1980,[4] to 8.5 per 1000 LB in 1990 and 5.1 per 1000 LB in 1998.[5] The outcome of very low birth weight (VLBW) babies has also been evaluated in a national study.[6] A cohort of VLBW babies was enrolled in 1993 and followed up till 1996. The survival rate was 62.6% in 1993 and 69.3% in 1996. Neurodevelopmental outcome at 2 years of age was assessed for 77 survivors out of a cohort of 150 VLBW infants born in 1993.[7] The mean general quotient on the Griffith's developmental scale of the 77 infants was 94 as compared 104 in a control group. Functionally 70.2% were normal, 23.3% had mild handicap, 1.3% moderate, 2.5% severe handicap and 2.5% multiple severe handicap.

While much of these improvements in perinatal and neonatal outcomes in Malaysia are due to the general improvement in living standards, it is likely that they are due in part to improvement in medical services in general and neonatal care services in particular. The publicly funded neonatal care service has come a long way since it first begun; from the basic neonatal care provided by nurses and medical officers to the modern well-equipped neonatal intensive care units (NICU) with neonatal-trained specialist staff. Clearly, the service deservedly consumes a significant proportion of the country's health care resource. However, in spite of the massive investment in new facilities, equipment and human resources into the service, it has never been subjected to rigorous economic evaluation. To our knowledge, hard objective data on the cost-effectiveness of neonatal care intervention are not available in this country. Although such data for neonatal care service are increasingly available from other countries,[8,9] results of economic evaluation have very limited generalizability across borders.

An economic evaluation of the service not only serves the need for public accountability, it also provides an objective assessment of the relative value for money of the service against other competing health services. Thus, economic evaluation can assist informed and rational decision-making on alternative uses of scarce health-care resources. As neonatal intensive care service is almost entirely publicly funded in Malaysia, and the care of VLBW infants consumes the major proportion of neonatal intensive care resources, we undertook this study to determine the cost-effectiveness of the care of VLBW infants as a measure of cost evaluation of neonatal intensive care services in Malaysia. However, as treatment then was not uniformly offered to infants below 1000 g birth weight in all centers, our study excluded babies of less than 1000 g birth weight.

METHODS

This was a multicenter observational study to determine the outcome, cost and cost-effectiveness of neonatal intensive care provided by the Ministry of Health (MOH) Paediatric services. Five NICUs from MOH hospitals participated in this voluntary study. The perspective taken is that of MOH. This is justified since the MOH is the ultimate decision-maker on the funding of its services. The objective of this cost-effectiveness analysis is to assist this decision-making process. Thus, only direct treatment costs borne by the MOH were included. Costs borne by patients include direct nontreatment costs (e.g. transport to hospital), indirect costs (e.g. lost work time) and intangible costs (e.g. pain and anxiety); these were excluded in this analysis. The time horizon was limited to 1 year after admission to NICU. Long-term costs and outcomes beyond the first year were not included.

Neonatal Intensive Care Outcome

To determine outcome, all infants of 1000 to 1500 g birth weight admitted to the five NICUs from January 1, 1999 to June 30, 1999 were enrolled retrospectively and data on their outcomes abstracted from medical records. A total of 333 infants enrolled were eligible for analysis according to the inclusion and exclusion criteria of this study. These criteria for inclusion were body weight between 1000 and 1499 g at birth including livebirths who died in labor room prior to transfer to NICU, admission within the first 28 days of life and absence of lethal congenital abnormalities. Outcome measured was survival at 1 year of age. Quality of life measure and its valuation are not available.

Costs

All costs are valued in year 1999 constant RM (RM 1 = US$0.263).

The cost categories identified and measured are:

1. Capital costs, which include land, building and capital equipment. All capital costs are annualized to year 1999. Building cost is amortized over 30 years at 3% discount rates. Equipment cost is adjusted for inflation using GDP deflator to year 1999 from its year of purchase, and then amortized over its estimated useful life at 3% discount rate. Land is not depreciated. The use of 3% discount rate is consistent with the shadow price of capital approach to evaluating public investments.[10–12]
2. Staff costs, which include full-time NICU staff, as well as part time staff such as Paediatric Department administrative, pharmacy and security staff. Only part of the costs of part-time staff are allocated to neonatal intensive care service in proportion to the estimated amount of time they spent on NICU-related work (for administrative and clinical staff) or using allocation rule based on relative build up area between NICU and the hospital (for security staff).
3. Overhead costs, which include administration and supportive services like laundry, cleaning, building and equipment maintenance, utilities and telephone. These were measured at the hospital or Pediatric Department level. Hence, part of these costs were allocated to the neonatal intensive care service provided by the Pediatric Department using various allocation rules based on relative floor area, staff strength, in-patients number, as appropriate for the cost item.
4. Patient care consumable costs, which include laboratory tests and X-ray, pharmaceuticals and surgical disposables, transportation, medical procedures and nonpediatric specialist services (surgery, ophthalmologist, radiologist, physiotherapists, occupational therapists, etc). To determine these costs, eight newly admitted patients were randomly sampled from each of the five participating NICUs and prospectively followed up to measure the consumables utilized over the course of their care till discharge from NICU. The product of the quantity of the resource used and its unit price give the cost of an item of resource identified. The quantity of resource used in each cost category is directly measured in this study. The unit cost is based on market price or purchase cost. These were available for all resource items identified in this study except for a few donated equipment, or equipment on loan from company. The costs of these equipments were imputed using prices of similar items. All costs are valued in year 1999 constant RM. Market or purchase price was used for all identified resources.

Both resource utilization (cost) and outcome data collected were subjected to quality control, which include queries of all suspect data based on predetermined rules and source data verification at site.

Cost-effectiveness refers to cost per survivor to 1 year of age. This is estimated by the ratio of cost per inpatient to the probability of survival to 1 year of age. Survival probability is estimated by the Kaplan–Meier method. Nonparametric bootstrap method[13] was used to obtain the standard error of cost-effectiveness ratio estimate and to set up 95% confidence interval. Sensitivity analysis was performed by varying the discount rate for cost (5%) and by using the minimum and maximum overhead cost estimates in the sample for all NICUs.

RESULTS

Sample

Table 1 shows the characteristics of the sample of 333 neonates studied. Among them, 291 neonates (87%) were in-born patients while 42 (13%) were outborn. The mean birth weight was 1255 g, with about 50% of the sample in each birth weight category of 1000 to 1249 and 1250 to 1499 g. The mean gestation of the sample was 31 weeks. In all, 41% were more than 31 weeks gestation, 50% of neonates were of 28 to 31 weeks gestation, while 8% were of gestation less than or equal to 27 weeks.

Table 1 Characteristics of Sample

Characteristics	$N = 333$
In-born status	
No. (%) In born	291 (87%)
No. (%) Out born	42 (13%)
Birthweight (g)	
Mean (SD)	1255 (143)
No. (%) 1000–1249 g	147 (44%)
No. (%) 1,250–1499 g	186 (56%)
Gestation (weeks)	
Mean (SD)	31 (3)
No. (%) ≤27 weeks	28 (8%)
No. (%) 28–31 weeks	167 (50%)
No. (%) ≥32 weeks	138 (41%)
NICU No. (%)	
A	59 (18%)
B	48 (14%)
C	43 (13%)
D	122 (37%)
E	61 (18%)

Outcomes

Table 2 shows the results for survival outcome at 1 year of age. Overall, survival probability at 1 year of age was 78%. As expected, there was an obvious trend in survival rate by birthweight and by gestation. Survival at 1-year of age was 77% for infants with birth weight 1000 to 1249 g, and 79% for those of 1250 to 1499 g. According to gestational age, survival at 1 year of age was 50% for 26 to 27 weeks gestation, 80% for 28 to 31 weeks and 80% for those of 32 to 36 weeks gestation. There was a marked variation in survival outcome between units, with the probability of survival to 1 year of age ranging from 0.52 to 0.91, giving an average of 0.78 (see Table 3).

Cost

Table 4 shows the cost of the care of study group infants among the five participating NICUs. Total cost per infant ranged from US$26 to US$3818. Of more interest is the cost profile. As expected, in all five NICUs, land cost was negligible while building accounted for a minor proportion of the total cost, ranging from 1 to 2.6%. Equipment costs was surprisingly small in view of the perceived heavy equipment input required by NICUs.

Table 2 Probability of Survival to 1 Year of Age

Factors	% Survival	95% CI
Overall	0.78	0.73, 0.82
Birthweight (g)		
1000–1249	0.77	0.69, 0.83
1250–1499	0.79	0.72, 0.84
Gestation weeks		
≤27	0.53	0.34, 0.70
28–31	0.80	0.73, 0.85
≥32	0.80	0.72, 0.86

Table 3 Birthweight, Gestation, Length of Stay and Probability of Survival in Study Group Patients in 1999 by Hospitals

	Hospitals					
	A	B	C	D	E	All
N	59	48	43	122	61	333
Mean birthweight (g)	1253	1285	1218	1274	1224	1255
Mean gestation (weeks)	31	33	30	30	30	31
Mean LOS (days)	35	37	39	39	29	36
Probability of survival at 1 year	0.69	0.89	0.74	0.91	0.52	0.78
95% CI	0.55, 0.79	0.76, 0.95	0.59, 0.85	0.84, 0.95	0.38, 0.65	0.73, 0.82

LOS = length of stay.

Staff costs constituted 23 to 31% of total costs per infant for four of the five hospitals but 44% in Hospital C, notably a two-fold difference due to twice a full-time equivalent (FTE) staff per infant. Table 5 shows the variation in staffing between the five hospitals. The other four NICUs had about 1 FTE staff per infant with Hospital A having the least number of fulltime medical specialist staff (earning more than US$1052 or RM 4000) and hospital B and E having a higher number of senior medical and nursing staff.

Consumable cost was expected to dominate the cost profile. This was true for four of the five NICUs, for which consumable costs was the largest cost category. In these four units, consumable costs

Table 4 Costs per Patient in 1999 by Hospitals

	A	%	B	%	C	%	D	%	E	%	All
Capital costs											
Land	4.21	0.2	24.74	0.8	1.84	0.1	23.95	0.7	3.42	0.1	11.63
Building	68.68	2.6	39.21	1.3	39.21	1	65.53	2	29.21	1.1	48.37
Equipment	118.42	4.4	340.53	11.2	103.95	2.7	188.42	5.6	162.37	6.1	182.74
Subtotal, Capital	191	7.1	405	13.3	145	3.8	278	8.3	195	7.4	243
Recurrent costs											
Staff	668.68	24.9	941.84	31	1686.84	44.2	771.32	23.1	603.68	22.8	934.47
Overhead	315.26	11.8	270.53	8.9	1099.21	28.8	611.05	18.3	517.37	19.6	562.68
Consumable	1507.37	56.2	1419.21	46.7	887.11	23.2	1677.63	50.3	1328.42	50.2	1363.95
Subtotal, Recurrent	2491	92.9	2632	86.7	3673	96.2	3060	91.7	2450	92.6	2861
Cost per in-patient (1999 terms)	2683		3036		3818		3338		2645		3104
95% CI	1887		2352		3466		2791		2280		2852
	3478		3720		4171		3885		3009		3356
CER (1999 terms)	3888		3411		5160		3668		5087		3979
95% CI	2603		2795		3797		3133		3453		3577
	5173		4028		6523		4203		6720		4382

Table 5 Staff Distribution and Full-Time Equivalent (FTE) Staff per NICU in 1999

	Hospital					
	A	B	C	D	E	All
FTE	88.2	42.5	86.3	136.9	44.7	398.6
In-patient days	30,693	12,781	13,798	47,741	14,170	119,183
No. of in-patients/day	84	35	38	130	39	326
FTE/in-patient	1.1	1.2	2.3	1.0	1.2	1.4
Distribution of FTE (%)						
Staff salary, RM						
$\geq$5000	1.0 (1)	1.2 (3)	2.5 (3)	2.1 (2)	1.1 (2)	7.9 (2)
4000–4999	0.3 (0)	—	—	1.4 (1)	—	1.7 (0)
3000–3999	—	0.5 (1)	—	—	—	0.5 (0)
2000–2999	7.6 (9)	13.1 (31)	18.0 (21)	15.2 (11)	11.5 (26)	65.4 (16)
1000–1999	78.4 (89)	25.4 (60)	58.1 (67)	104.5 (76)	28.8 (64)	295.2 (74)
<1000	0.9 (1)	2.3 (5)	7.7 (9)	13.7 (10)	3.3 (7)	27.9 (7)

Note: US$1 = RM 3.8.
Total in-patient days include infants not enrolled in the study group (<1000 and >15000 g birth weight) admitted to NICU.

accounted for 47 to 56% of total cost. The one exception, Hospital C, had the lowest consumable cost per infant (in percentage and absolute terms) accounting for only 23% of total cost per patient.

Cost-Effectiveness

Table 4 shows the cost-effectiveness of care of the study group infants. Among the five NICUs, the cost-effectiveness ratio (CER) varies from US$5160 (Hospital B) to US$5160 (hospital C) per survivor at 1 year of age. Overall, the CER was US$3979 per survivor at 1 year of age (95% confidence interval US$3577, 4382).

Sensitivity analyses (Table 6) show that the CER results were robust to choice of 5% discount rate and to uncertainty in valuing overhead costs. The relative ranking of the CER of the five NICUs were largely unchanged by the use of 5% discount rate or the use of minimum and maximum overhead costs in the sample.

DISCUSSION

The CER of the MOH neonatal intensive care service at US$3979 per survivor at 1 year of age compares very favorably with those of developed countries in the 1980s (Tables 7 and 8). In the United States, the CER for aggregate treatment costs/first-year survivor (in 1999 US$ terms) was US$40581 for infants of birth weight between 1000 and 1249 g and US$28285 for those of birth weight between 1250 and 1499 g.[18] Labor cost is typically the most expensive item in the delivery of neonatal intensive care. This is not reflected in our study, accounting for only 20 to 30% of the cost in our study group. This can be explained by the comparatively low remuneration of government health staff, including neonatal specialist doctors and nurses in Malaysia. Consumables make up the highest costs component in the NICU because most of these consumables are imported.

There is marked variation in survival outcome at 1 year of age, ranging from probabilities of 0.52 to 0.91. Several factors could account for this variation. There was differing ease of usage of surfactant among the NICUs. Use of surfactant as rescue therapy in infants with respiratory distress syndrome and birth weights between 700 and 1350 g has been shown to result in significantly improved survival without increased costs.[22] Other variable factors not studied are antecedent factors such as accessibility to antenatal care and use of antenatal steroids that has been shown unequivocally to reduce the incidence of respiratory distress syndrome and its attendant complications,[23] and variable nosocomial infection rate in the NICUs.

Our data also show considerable variation in resource inputs among the five NICUs. This is particularly striking for staff strength and possibly skills, equipment and consumables (Table 4). No doubt, this is largely a result of historical pattern of budget allocation, rather than any conscious decision by health service manager to deny or over endow any particular unit with resources. However, the outcome is typically marked variation in cost-effectiveness among units as shown in this study. There ought to be considerable opportunities for cost-saving here. Given that Hospitals B and D (the ones with the highest equipment costs) were the most cost-effective and Hospital C (the one with the lowest equipment cost) was the least cost-effective, one of the other factors to look

Table 6 Sensitivity Analysis of CER

Hospital	CER, RM per survivor at 1 year of age					
	A	B	C	D	E	All
Cost at 5% discount	3937	3478	5191	3726	5133	4029
Overhead cost						
Minimum	3823	3411	4040	3294	4611	3605
Maximum	5024	4343	5160	4204	6206	4667

Table 8 Comparison of Costs of Care of VLBW Babies

Studies	Economic evaluation	USD (1999 terms)
Our study	Per survivor to one year	3980
Rogowski[18]	Per additional livebirth to discharge	26,990
Stolz and McCormick[19]	Per additional survivor	46,624
Tudehope et al.[20]	Per survivor at discharge	5087
Pharoah et al.[21]	Per survivor to discharge	12,903
Boyle et al.[9]	Per additional survivor at discharge	20,263

Table 7 Survival Outcomes of VLBW Infants in Developed Countries

Study	Year of study	Country	Study population	Outcome
Lemons et al.[14]	1995–1996	USA	4438 infants BW 501–1500 g	84% overall survival to discharge
Hack et al.[15]	1989–1990	USA	1804 infants BW ≤1500 g	78.6% overall survival to discharge or 120 days
Horbar et al.[16]	1983–1984	USA	1776 infants BW 701–1500 g	85% survived 28 days
Chang et al.[17]	1995–1998	Taiwan	162 infants BW <1500 g	78.4% survival to discharge
This study	2000	Malaysia	333 infants BW 1000–1500 g	78% overall survival to 1 year of age

at in order to improve cost-effectiveness would be the appropriate allocation of medical equipment and its corresponding use of consumables. With improved patient outcome and better resource allocation and utilization, the Victorian Infant Collaborative study group[24] showed that the CER of neonatal intensive care in the 1990s (if only initial hospitalization costs were considered) for infants of between 500 and 999 g birthweight in Victoria, Australia had reduced to as low as US$801 (in 1999 US$ terms). This suggests that the cost of neonatal care for the extremely and VLBW babies can be further reduced with increased experience over time.

The outcome and therefore, the cost-effectiveness of neonatal intensive care also depends on the experience, skill and numbers of the NICU staff. The number of full-time equivalent (FTE) staff in all four NICUs except Hospital C was between 1 and 1.2 FTE per inpatient per day (or 0.33 to 0.4 FTE staff per patient per shift). Such variation is probably expected since staffing level tends to be dictated by historical pattern of employment in a unit rather than directly linked to workload. However, the importance of the role of staff resource in this study cannot be fully evaluated in view of limited data.

The results of this evaluation should be interpreted cautiously. The main weakness is the overhead cost estimates. These were based on report by hospital administration rather than micro-costing performed at individual overhead departments. Fortunately, the CER results were relatively insensitive to this. We have used survival to 1 year of age as the sole measure of outcome in this evaluation. In view of the retrospective nature of the data collection for the outcome part of the study, only survival outcome could reasonably be determined accurately. Costs related to intercurrent illnesses, postdischarge neurological problems or dysfunction were not included. Rehospitalization rate was given in a recent study as 35.2% for those babies with birth weights between 1240 and 1499 g, but 58% have only one episode of rehospitalization in the first year of life.[25] Extrapolating from this study with a rehospitalization cost of US38/survivor, this exclusion is not anticipated to contribute markedly to overall costs of our survivors in the first year of life.

In conclusion, it does appear that the Ministry of Health neonatal intensive care services are cost-effective as compared to neonatal services in developed countries. This is largely due to cost-savings in labor cost in terms of amount of emoluments and, although not directly studied here, lower staff to patient ratios.

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