Evaluating services for perinatal asphyxia and low birth weight at two hospitals in Ghana: a micro-costing analysis

Christabel C Enweronu-Laryea[1], Eric Nsiah-Boateng[2], Hilary D Andoh[3], Audrey Frimpong-Barfi[4], Francis M Asenso-Boadi[5,6] and Moses Aikins[2]

Ghana Med J 2019; 53(4): 256-266 doi: http://dx.doi.org/10.4314/gmj.v53i4.2

[1] Department of Child Health, University of Ghana School of Medicine and Dentistry, Ghana
[2] School of Public Health, College of Health Sciences, University of Ghana, Accra, Ghana
[3] Greater Accra Regional Hospital, Ghana Health Service, Accra, Ghana
[4] Tema General Hospital, Ghana Health Service, Greater Accra Region, Ghana
[5] Departments of Economics, University of Cape Coast, Ghana
[6] Head Office, National Health Insurance Authority, Accra, Ghana

Corresponding author: Christabel Enweronu-Laryea **E-mail:** ccelaryea@ug.edu.gh
Conflict of interest: None declared

SUMMARY

Background: Neonatal mortality has been decreasing slowly in Ghana despite investments in maternal-newborn services. Although community-based interventions are effective in reducing newborn deaths, hospital-based services provide better health outcomes.
Objective: To examine the process and cost of hospital-based services for perinatal asphyxia and low birth weight/preterm at a district and a regional level referral hospital in Ghana.
Methods: A cross-sectional study was conducted at 2 hospitals in Greater Accra Region during May-July 2016. Term infants with perinatal asphyxia and low birth weight/preterm infants referred for special care within 24hours after birth were eligible. Time-driven activity-based costing (TDABC) approach was used to examine the process and cost of all activities in the full cycle of care from admission until discharge or death. Costs were analysed from health provider's perspective.
Results: Sixty-two newborns (perinatal asphyxia 27, low-birth-weight/preterm 35) were enrolled. Cost of care was proportionately related to length-of-stay. Personnel costs constituted over 95% of direct costs, and all resources including personnel, equipment and supplies were overstretched.
Conclusion: TDABC analysis revealed gaps in the organization, process and financing of neonatal services that undermined the quality of care for hospitalized newborns. The study provides baseline cost data for future cost-effectiveness studies on neonatal services in Ghana.

Keywords: perinatal asphyxia; low-birth-weight; time-driven activity-based costing; process of care
Funding: Authors received no external funding for the study

INTRODUCTION

Infant mortality rate, infant deaths per 1000 live births, is an indicator of the health and wellbeing of nations. Most infant deaths occur in the first 28 days after birth – the newborn period, and an estimated 2.6 million newborns died in 2016.[1] Most newborn deaths are preventable and the major causes are perinatal asphyxia, low birth weight (LBW)/preterm birth, and infections.[2] Community-based maternal-newborn interventions are cost-effective strategies for reducing newborn deaths,[3-5] but hospital-based services lead to better health outcomes.[6,7]

In Ghana, perinatal asphyxia and LBW/preterm are leading causes of neonatal mortality and all-cause mortality, but the burden of neonatal infections is uncertain due to challenges in accurate diagnosis.[8,9] Neonatal mortality rate has been declining relatively very slowly[10] despite investments in infrastructure, developmental assistance from partners, and a National Health Insurance Scheme (NHIS) that provides free hospital-based maternal-newborn services. The NHIS is a nationwide social health insurance scheme with a fee for service (FFS) payment mechanism for medicines.

The NHIS significantly improved care-seeking behaviour and maternal health outcomes but has had less impact on under-5 child mortality.[11,12] About 40% of under-5 deaths and 60% of infant deaths in Ghana occur in the newborn period.[13] A closer scrutiny of the process of care for inpatient neonatal services is needed to ascertain why investments in maternal-newborn health have not resulted in expected reduction in neonatal deaths.

A review of the literature showed limited published economic evaluation specific for inpatient neonatal services in Ghana.[14] This study sought to determine the best estimate of actual cost of neonatal services for babies with perinatal asphyxia and LBW/preterm at a district and regional hospital by using a micro-costing approach that examined the process of care. The economic cost of hospital-based neonatal services on families has been described elsewhere.[14] This paper reports findings from providers' perspective.

METHODS

Newborns were categorised by gestational age, birth weight and clinical parameters using universal criteria and NHIS Ghana Diagnostic-Related Group (G-DRG) (Table 1). Perinatal asphyxia and LBW are specific G-DRG categories.

Table 1 Eligibility criteria for time-driven activity-based costing of neonatal care

General criteria	
Age at admission <24hours	
Mother reachable in person or by phone	
Father (or relative responsible for mother and baby) reachable in person or by phone	
No obvious congenital abnormality	
Written informed consent by parent(s)	
Birth asphyxia criteria	
Maturity criteria:	Gestational age ≥37 weeks
Weight criteria:	Birth weight 2500-3999 grams
Evidence of foetal distress:	Abnormal cardiotocography or partograph
	Required bag and mask resuscitation at birth
Evidence of neurological deficit:	Weak/absent cry at birth
	Weak/absent suck
	Abnormal muscle tone
	Seizures
Low Birth Weight (LBW) / Preterm criteria	
Maturity criteria;	Gestational age <37weeks
Weight criteria (categorized):	Less than 2500grams
	LBW: 1500-2499grams
	Very LBW (VLBW): <1500grams
	Extremely LBW (ELBW): <1000grams

Using a cross-sectional design, eligible newborns were recruited within 24 hours after birth. Time-driven activity-based costing (TDABC) approach[15] was used to document and cost all activities in the full cycle of care from admission until discharge or death during May to July 2016.

TDABC is a micro-costing approach that is linked to the value-based healthcare agenda.[16] It prioritizes accuracy over precision and requires two key parameters, the capacity cost rate and time used to perform healthcare activities. TDABC approach requires healthcare providers to estimate only two parameters at each process of the care pathway: the cost of each resource used and the quantity of time the patient spends with each resource. In this way, providers are able to assign costs accurately and relatively easily to each process step along the care pathway.[16-18]

Setting

The Ghana Health Service (GHS) implements the objectives and policies of the Ministry of Health (MoH). MoH provides major inputs (infrastructure, human resource, equipment) to public regional and district hospitals nationwide. Ghana had 10 administrative regions in 2016 and each region has a referral regional hospital and several district hospitals. The study was done in Greater Accra Region with permission from the Regional Health Directorate and approval by the Ethics Review Committee of GHS (GHS-ERC 77/02/16).

Each study site, regional hospital (RH) and the largest district hospital (DH), provided comprehensive obstetric and neonatal care to about 9,000 births and 1500 newborn inpatients in an urban setting yearly. In 2016, both hospitals had limited space and infrastructure for neonatal services and provided similar inpatient services to similar categories of sick and/or small newborns. The services included resuscitation, intravenous infusions and medicines, blood transfusions, oxygen therapy, gavage feeding and kangaroo mother care (KMC). Characteristics of the neonatal units are described in Table 2.

Study procedures

After ethical approval, the protocol was shared with the clinical team (doctors and nurses) of each neonatal unit. Thereafter, a meeting was held with each team to: discuss the protocol and data collection tools; understand and harmonize the care delivery value chain (Supplementary file 1) and process of service delivery (Supplementary file 2); plan the pilot study; and identify lead nurses and doctors who would ensure 24/7 accurate data entry.

The protocol and tools were modified based on input from clinicians and lessons learnt from the pilot study on 10 babies, who were excluded from the study sample.

In 2016, both hospitals lacked electronic medical records system and precision of time data as recommended in Kaplan's TDABC[15] was not practicable because of insufficient human resource and clinical workload.

The duration of clinical processes was recorded during the pilot study and the average time per process of care was adopted as standard in the 24-hour clinical activity tool (Supplementary file 3) which captured all activities in the process of care. The duration of complex processes that required longer periods of time were captured.

Table 2 Characteristics of neonatal units at regional hospital (RH) and district hospital (DH) during May to July 2016

Item	Regional hospital	District hospital	Remarks
Bed capacity in neonatal ward	20	37	Number on admission daily: RH: 30 – 35 DH: 27 – 39
Kangaroo mother care beds	6	4	
Admissions (deaths): **May – July 2016**	324(55)	545(62)	
Doctors			
Specialist (Paediatrician)	2	1	Overall administrative head
Medical Officer	2	1	
Senior House Officer	4	4	
Organization of care (rota) Morning Day cover Night duty (on-site)	 4–5 1–2 1	 3-4 0-1 0	 5 – 8pm 8pm – 8am
Nurses			
Principal Nursing Officer	0	1	In charge, ward administration
Senior Nursing Officer	3	1	
Nursing Officer	1	1	
Senior Staff Nurse/Midwife	5	2	
Staff Nurse/Midwife	6	2	
Enrolled Nurse	4	2	
Rotation/Student nurse	2	5	
Organization of care rota/shift: Morning Afternoon Night	 5 3–4 2-3	 2 2 2	 8am – 2pm 2pm – 8pm 8pm – 8am
Equipment available and used in neonatal unit			
Radiant warmer	4	2	
Incubator	6	5	
Bassinet/Cot	10	30	
Phototherapy	5	7	
Cardiorespiratory monitor	3	0	
Pulse oximeter	4	3	
Suction equipment	3	1	
Resuscitation (bag and mask)	20+	10+	
Weighing scale	2	2	
Oxygen concentrator	1	2	
Refrigerator	1	1	
Supplies for clinical care			
Linen, pulse oximeter probe, nasal prong, face mask, thermometer, kidney dish/gallipot, connection tubes for oxygen and suction equipment			Cleaned and re-used between several patients (not costed)
Infusion set, vascular cannula, syringe/needle, feeding tubes, sterile/disposable gloves			Single use supplies provided by the hospital (costed)
Hygiene supplies, feeding cups, glucometer strips, formula, diapers			Donations or out-of-pocket payments (costs excluded)
Oxygen cylinders (not costed)	RH: Every patient paid $19 flat rate out-of-pocket. DH: Leased by parents ($10 small size, $20 large size) when supply from oxygen concentrator is insufficient		

To capture all activities in the process of care, we applied the 24-hour clinical activity tool at the time of admission of all eligible newborns but only enrolled those whose parents subsequently gave written informed consent within 48 hours of hospitalisation. Health workers on duty ensured all clinical activities on participants were documented in the tool. The data was cross-checked with medical and nursing records by the research team. The 24-hour clinical activity tool was completed daily from the time of admission until discharge or death.

Standards for equipment in neonatal care at district and regional hospitals were obtained from GHS. To estimate the cost of other resources (indirect costs) and activities (overhead costs) required for providing care, the head of finance department at each hospital and the paediatrician and nurse in charge of the newborn units were consulted. Input cost allocation for equipment was based on 2015 UNICEF equipment and supplies list for neonatal services in Ghana, University of California equipment useful life table for depreciation[17] and American Hospital Association's estimated useful lives of depreciable hospital assets.[18] The MoH Single Spine Salary Scale for 2016 was used for personnel cost allocation.

Data analysis

Although the plan was to cost all inputs, accurate costing was only feasible for personnel, equipment and single use supplies (Table 2). Providers' indirect, overhead and support centre inputs were not costed because it was not possible to accurately establish and disaggregate inputs used in neonatal services at the study sites. The hospitals were colonial era buildings with very limited space; the hospitals and MoH had no data on utility bills and other infrastructural costs from which neonatal services could be disaggregated. Analyses were conducted with Microsoft excel version 10 and costs reported in United States dollars using currency conversion rate during the conduct of the study (1 dollar = 3.95cedis).

Estimation of personnel cost: All personnel were full-time employees of GHS and were paid by MoH. The category of personnel (Table 2) who attended to each newborn and contact episodes during hospitalisation was tabulated. Each infant's personnel cost was estimated by first dividing the average consolidated monthly income for that category of personnel e.g. medical officer, senior staff nurse, by 224 hours (8 hours a day for 28 days) to obtain the capacity cost rate (or unit cost per hour). The capacity cost rate was then multiplied by the respective number of personnel (or quantity) in that category and the time the newborn spent using the personnel; this was done for all categories of personnel involved in the care of each newborn to obtain the total capacity cost rate. We excluded all statutory leave and time-off on the clinical care rota from the personnel's available time for work.

Estimation of equipment cost: The equipment used for each newborn and duration of use was tabulated. Equipment were at full capacity as most were insufficient in number to meet need. The cost of each equipment was calculated by dividing the unit cost of the equipment by its estimated number of years of useful life to obtain the annual financial cost (AFC). Estimation of AFC was to account for straight-line depreciation of the equipment. Annual cost of equipment usage (equipment cost allocation) for each newborn was determined by dividing the number of hours the newborn spent using the equipment during the entire period of hospitalization by the number of hours in a year (8760 hours). Each infant's equipment cost was then estimated by multiplying the AFC by the proportional allocation or shared cost of the equipment. Infrastructure (basic bed and bedside furniture) in both KMC wards were not costed because they were donations and financial data was not available.

Estimation of supplies cost: All single use supplies (Table 2) applied to each newborn during the entire period of hospitalisation was tabulated. The total number of each supply was multiplied by the unit cost of that supply to obtain the total cost. Single use supplies that were cleaned and reused on several newborns were not costed.

Estimation of total cost of hospitalization: The total direct cost of hospitalization for each newborn was estimated by adding the cost of personnel, equipment and supplies. Average direct cost was determined by dividing the total cost of hospitalization by the number of newborns in the G-DRG. Similarly, the daily direct cost was estimated by dividing the total cost of hospitalization by total length of stay (LOS) in days. The estimations of the total costs of hospitalization and cost per newborn were disaggregated by type of hospital, diagnosis, and category of birth weight.

Sensitivity analysis: A one-way sensitivity analysis (SA) was conducted using different values of estimated years of useful life of each equipment. The estimated years of useful life were reduced from 15 years to 10 years based on the assumption that the equipment may experience frequent breakdowns because they were being used at full capacity. Secondly, equipment may be used inefficiently because some health workers may have inadequate knowledge of how to operate them. SA was undertaken to account for measurement errors that might have occurred from estimation of hospitalization cost such as omission of important cost components; inappropriate timeframe for the study, for example, a short timeframe of three months might lead to under or overestimation of treatment cost of the two conditions studied.[19,20]

The SA was also undertaken to test the robustness of the study findings, build accuracy and reliability into the analysis model, and strengthen the confidence of the study for generalisability.[19-21]

RESULTS

During the 3 months, 869 newborns were admitted to both hospitals and 496 (perinatal asphyxia 159, LBW/preterm 337) were eligible for the study. Data was collected from 62 babies of 58 mothers comprising 27 cases of perinatal asphyxia and 35 cases of LBW/preterm.

The most common reasons for exclusion were uncertainty of gestational age, poor documentation of intrapartum parameters indicative of foetal distress and level of resuscitation at birth and absence of parents for informed consent process within 48hours after birth. Most eligible infants had more than one exclusion criteria.

About 1 out of 5 admissions (18.3%, 159/869) was a term normal birth weight infant with presumed perinatal asphyxia. None of the parents of newborns who met all the inclusion criteria declined participation. Length of stay (LOS) varied from 2 – 41 days, other characteristics of participants is summarized in Table 3. Clinical and cost data of 62 babies (including non-surviving infants) during 757 patient days were analysed.

Table 3 Characteristics of hospitalised newborn participants

Diagnostic Related Group	Perinatal asphyxia		Low birth weight/preterm	
Level of hospital	Regional	District	Regional	District
Maturity and birth weight				
Term, normal birth weight	15	12		
Preterm, low birth weight (LBW)			12	23
- **LBW (1500-2499g)** - **Very LBW (1000-1499g)** - **Extremely LBW (<1000g)**			7 4 1	10 9 4
Length of stay (LOS)				
0-7days **8-14days** **15-28days** **29-42days** ***Average LOS**	7 6 2 - 10	10 2 - - 4.6	1 3 6 2 18.6	8 7 5 3 14.3
Outcome				
Died **Discharged**	1 14	0 12	1 11	3 20

***** No difference in LOS for LBW/preterm at regional and district levels of care ($p = 0.2$); LBW/preterm had significantly longer stay than infants with perinatal asphyxia ($p = 0.0006$); infants with perinatal asphyxia at regional hospital had significantly longer stay than those at district hospital ($p = 0.005$).

Organization of neonatal services

Each neonatal unit was part of the paediatric department. The neonatal unit at RH had an open architectural plan with the nursing station in the middle of the ward, while the unit at DH comprised of 3 cubicles with the nursing station outside the clinical area. All documentation was handwritten. Nurses were permanent personnel of the neonatal unit; doctors had rotations between paediatric wards and the neonatal unit but the doctors remained essentially unchanged during the study. Most of the administrative, clerical and hygienic services were done by nurses.

Senior nurses were responsible for clerical and administrative services and also performed clinical work. The nurse on duty provided clinical care and performed hygienic procedures including general care and cleaning of equipment and supplies. Hospital domestic staff cleaned the floor once daily. Personnel rota and other inputs are summarized in Table 2.

Although both hospitals had laboratory and radiological services, these were not available at the point-of-care. Parents served as porters for laboratory services. Overall, medicines, most laboratory services, and basic clinical and hygienic supplies were paid out-of-pocket by parents at both hospitals irrespective of NHIS cover status.

Most newborns were not accompanied by a parent at the time of admission, but each neonatal unit had stock of emergency supplies and medicines which were replaced by parents later.

Process of care

The process of care and data collection procedures are described in Supplementary file 1.

Mothers played an active role in cleaning and feeding their babies. Both hospitals had guidelines for neonatal care (admissions, referrals, diagnostics, medications and discharge), parents' visits and documentation. The newborn units operated beyond capacity for all types of resources. Except for emergency procedures and medicines, other diagnostic and treatment procedures were largely dependent on parent's physical presence and ability to pay.

Table 4 Components of direct costs of hospital services for newborn infants

Diagnostic related group	Perinatal asphyxia		Low birth weight/Preterm	
Level of hospital **(cases)**	Regional (15)	District (12)	Regional (12)	District (23)
Personnel cost ($)				
Specialist (Paediatrician)	168.96	126.72	190.08	1668.49
Medical Officer	201.9	422.78	155.02	3297.69
Senior House Officer	1904.04	800.25	1973.03	3946.05
Principal Nursing Officer	1339.12	195.97	1437.11	3135.5
Nursing Officer	936.56	438.64	1138.09	4267.86
Senior Staff Nurse/Midwife	3812.68	2295.26	7510.6	12917.22
Enrolled Nurse	694.53	409.41	614.11	2851.23
Total cost	**9057.79**	**4689.03**	**13018.04**	**32084.03**
Equipment cost ($)				
Radiant warmer	107.33	26.37	131.68	84.72
Incubator	5.46	5.27	200.32	395.9
Bassinet/Cot	4.3	1.84	0.84	3.2
Phototherapy	3.34	5.57	14.11	52.24
SPO2 monitor	7.92	3.45	8.44	19.21
Suction equipment	0.18	0.35	0.18	0.57
Bag and mask	0.06	0	0.04	0.32
Weighing scale	0	0.07	2.66	1.17
Oxygen concentrator	2.58	3.45	0.66	16.93
Infusion pump	0.04	0	0.11	0.03
Total cost	**131.21**	**46.37**	**359.04**	**574.29**
Supplies cost ($)				
Feeding tube	7.28	0.26	7.54	6.5
Giving set	1.71	1.08	1.98	2.16
Intravenous cannula	8.1	5.55	15.3	24
Syringe and needle	12.87	5.82	13.41	27.87
Sterile gloves	8.06	3.12	22.08	13.52
Disposable gloves	19.55	5.75	10.8	15.99
Total cost	**57.57**	**21.58**	**71.11**	**90.04**
*Grand total cost	**9246.57**	**4756.98**	**13448.19**	**32748.36**

* Cost of care for LBW/preterm significantly higher than for perinatal asphyxia at regional (p = 0.002, 95% CI 253.5– 754.9) and district (p = 0.008, 95% CI 283.2–1771.6) level.

Supplies were severely limited. One oxygen source was sometimes shared between 2 – 4 babies, 2 – 3 unrelated newborns shared an incubator for warmth or a cot for phototherapy. Continuous physiological monitoring equipment was lacking for most babies on oxygen therapy. Infections were presumed a major cause of morbidity and most newborns (60/62) received empirical antibiotic therapy as parents were either not physically available or financially capable to organize and pay for laboratory tests. None of the infants had a radiological investigation. Of the 32 that had laboratory tests (full blood count 26, serum bilirubin 15, blood culture 13, glucose-6-phosphate dehydrogenase 5, liver function test 1) most parents paid out-of-pocket and 17/32 parents provided proof of payment.

Each baby was assessed by a doctor at least once daily and on average had contact (assessment, procedures) with a nurse about 5 times daily. Babies at RH had vital signs (temperature, respiratory rate and heart rate) checked 3 times daily but most babies at DH, irrespective of birth weight, had single temperature assessment daily. Doctors were responsible for invasive procedures like insertion of vascular cannula, but nurses also performed these procedures at DH during night duty when there is no doctor in the unit (Table 2).

Stable very LBW/preterm infants were transferred to the KMC ward where mothers provided care under the supervision of one nurse during day shift. LBW/preterm infants at RH spent 55.4% of hospitalisation days in a warmer (incubator or radiant warmer) and 35.7% in the KMC ward while infants at DH spent 62.3% in a warmer and 14.2% in the KMC ward.

Overall, there was no difference in LOS for LBW/preterm at both hospitals (*p* = 0.2), but infants with LBW/preterm had significantly longer stay than those with perinatal asphyxia (*p* = 0.0006). Infants with perinatal asphyxia at RH had significantly longer stay than those at DH (*p* = 0.005).

Table 5 Direct cost of care and reimbursement rates at regional and district levels of care

	Perinatal asphyxia		Low birth weight/Preterm	
Level of hospital	Regional	District	Regional	District
Number of newborns	15	12	12	23
Total LOS (days)	150	55	223	329
Average LOS (days)	10	4.6	18.6	14.3
Cost of care ($)				
Grand total cost	9246.57	4756.98	13448.19	32748.36
Daily cost	61.64	95.14	60.31	99.54
Mean cost (SD)	616.44(105.07)	396.42(299.89)	1120.68(458.77)	1423.84(1240)
Range	183.88–1383.19	24.18–1064.84	378.71–1810.65	109.7–4756.57
Median cost	575.57	315.96	1031.3	1097
Interquartile range	417.23–768.72	208.52–472.94	897.48–1793.11	555.35–1662.17
Ghana-DRG reimbursement rate	77.04	54.42	109.87	77.12
LOS: length of stay; SD: Standard deviation; DRG: diagnostic-related group				

Cost of care and outcome

Personnel costs constituted about 95% of direct costs for both diagnostic-related groups at both hospitals. About 63.5% (range 53–73%) of personnel cost was from activities of junior professionals, senior house officers and staff nurses. The cost of services is summarised in Tables 4 and 5. Cost of care for LBW/preterm was significantly higher than that for perinatal asphyxia (RH: p = 0.002, 95% confidence interval (CI) 253.5– 754.9; DH: p = 0.008, 95% CI 283.2–1771.6). There was no significant difference in the cost of care for each diagnostic-related group between the hospitals (p=0.24 perinatal asphyxia, p = 0.42 for lbw/preterm). For LBW/preterm, personnel cost was higher at DH and contributed to the higher cost of care (Table 6). Daily cost of care was similar for the three categories of LBW at each hospital. Three out of 4 extremely LBW at DH died and 59.5% ($3322.14) of total costs in this weight category was from the surviving infant (Table 6). Overall 5 (8.11%) participants died (Table 3).

Table 6 Direct costs for categories of low birth weight infants

Level of care	**Regional hospital**			**District hospital**		
Birth weight category	LBW	VLBW	ELBW	LBW	VLBW	ELBW
Cases	7	4	1	10	9	4
LOS in days						
Total LOS	125	66	32	117	166	46
Average LOS	17.9	16.5	32	11.7	18.4	11.5
Cost of care ($)						
Personnel cost	7369.94	3889.65	1758.45	12249	14389.15	5445.88
Equipment cost	208.85	106.86	42.85	188.23	268.48	117.56
Supplies cost	37.95	23.8	9.36	35.96	37.7	16.38
Overall total cost	7616.74	4020.31	1810.66	12473.19	14695.33	5579.82
Cost per newborn	1088.11	1005.08	1810.66	1247.32	1632.81	1394.96
Daily cost	60.93	60.91	56.58	106.61	88.53	121.30
LBW: low birth weight (1500-2499g); VLBW: very low birth weight (1000-1499g); ELBW: extremely low birth weight (<1000g); $: United States dollars; LOS: length of stay						

Results of the one-way sensitivity analysis show no substantial differences between the base values of the overall cost of hospitalization for newborns and cost per newborn when the 15 years estimated useful life of the

equipment was changed to 10 years. Both overall cost of hospitalization and cost per newborn decreased by 0.024% for birth asphyxia versus 0.004% for LBW/preterm at the regional hospital. At the district hospital, overall cost of hospitalization and cost per newborn decreased by 0.01% for both birth asphyxia and LBW/preterm.

DISCUSSION

The study evaluated the financial cost of inpatient care for perinatal asphyxia and LBW/preterm to healthcare providers by examining the process of clinical activities in the full cycle care. Severe deficiency of resource inputs and ineffective organization and financing of clinical services undermined the quality of care provided. Personnel costs accounted for most costs and cost of care was higher for LBW/preterm than perinatal asphyxia. Costs were proportionately related to LOS and LBW/preterm had longer hospitalisation and higher utilization of all resources as described in high-resource settings.[22,23] Neonatal intensive care is labour-intensive and high personnel costs is recognized in all settings, however, direct costs from equipment may be higher than personnel costs in settings using expensive interventional technologies.[23]

Burden of disease and organization of care

The burden of LBW/preterm in neonatal units is recognised universally, but the burden of term perinatal asphyxia, a largely preventable condition, was high in this cohort. The total direct cost to GHS for providing basic intensive care for 27 newborns with perinatal asphyxia was $14,003. Survivors of perinatal asphyxia have high risk of neurodevelopmental disability and require rehabilitation services which are severely limited in Ghana.[24-26] Given the high burden of perinatal asphyxia in Ghana,[8] the long-term intangible costs to the health system and society should be acknowledged.[27,28] Strengthening the health system to deliver integrated comprehensive maternal-newborn services to tackle upstream determinants of poor birth outcomes is essential.[27,29,30] For LBW/preterm, scaling up appropriate use of antenatal corticosteroids for preterm labour should be considered; it may reduce cost of hospitalization.[31]

Effective organization of hospital services is critical to providing quality care and improving health outcomes. The neonatal units lacked ancillary personnel for non-clinical services and depended on nurses and parents to provide these services. Also, most vital paraclinical services were unavailable at the point-of-care and required the physical presence and ability-to-pay of parents before they could be provided to the sick infant. This organizational approach may have reduced overhead costs for the hospitals, but it overstrained clinical personnel, fostered non-evidence-based clinical practices and undermined the quality of care provided. Non-evidence-based practices prolong hospitalization, increase direct costs for providers, and undermine health outcomes.[9,31]

Resource utilization and cost of care

The neonatal units operated beyond capacity for all resources including bed space and confirms the postulation by Lambon-Quayefio *et al.*[32] They used data from the Ghana Demographic and Health Survey 2014 to assess the impact of NHIS on neonatal outcome and found that although NHIS made neonatal services more affordable to the population, women in urban areas with valid health insurance had significant increased risk of neonatal death irrespective of maternal education and wealth status. They attributed the situation in urban areas to overstretched health facilities and substandard neonatal services.

In high-income countries, TDABC analysis almost consistently reveal waste in the process of care, this study found the converse.[33] All resources were overstretched at both hospitals. Two nurses on night duty at DH attended complicated births, admitted out-born referrals, and provided clinical, nutritional and hygienic services to over 30 infants with varying degrees of illness. Single use supplies were cleaned and reused on several infants and unrelated infants shared bed space for phototherapy. These cost-cutting circumstances reduced costs for providers but made hospitalisation high-risk for newborns.

The cost of supplies was a very small fraction (0.3% – 0.6%) of the total direct costs. This may have been due to the practice of reusing single use supplies which were routinely cleaned by nursing staff with hygienic products provided (paid out-of-pocket) by parents. These supplies were not costed. Single use supplies are critical for preventing healthcare-associated infections, a major cause of death and prolonged hospitalization.

Procedures for cleaning and preparing non-single use supplies to reduce healthcare-associated infections may lead to significant overhead costs but these procedures were not performed at the study sites. We recommend a comprehensive review of products (supplies) required for inpatient neonatal services in Ghana and provision of a standardized and costed list of supplies to guide provider's financial planning and NHIS reimbursement rates.[34,35]

Unexpectedly, costs for LBW/preterm at DH was higher than at RH (Table 4 and 5). There are three possible explanations. First, the difference in the design of the neonatal units may have resulted in underestimation of clinical observations by clinicians at RH. Unlike DH, the open design and central workstation at RH enabled easy visualisation of all babies from the workstation; RH personnel could have observed the status of participants without recording the activity in the study tool. Secondly, DH had fewer KMC beds and LBW/preterm infants stayed in incubators for longer periods leading to higher personnel and equipment costs (Table 6). Incorporating KMC into acute neonatal services significantly reduces costs.[36] Thirdly, RH personnel could have had higher levels of skill sets and experience leading to different efficiency levels between the two facilities.

Limitations

Micro-costing methods are more precise and accurate but less generalizable. However, a detailed description of care processes and costing approach provided in this paper can guide healthcare providers with similar circumstances to review the process and value of services they provide. Secondly, the sample size of 62 babies may be relatively small, but overall 12.5% of eligible newborns were recruited despite the well-recognized rigour and expense of micro-costing studies and the strain it may have in settings with limited human resource for direct observation in the absence of electronic medical records. Existing guidelines on economic evaluations do not provide specific recommendations for sample size in micro-costing studies.[37] Thirdly, although neonatal infections cause significant neonatal morbidity and mortality, its effect could not be estimated due to limitations in diagnostic services provided at the study sites.

Fourthly, providers' indirect, overhead and support centre inputs were not costed because it was not possible to accurately establish and disaggregate inputs used in neonatal services. For instance, support resources such as office space and furnishings, procurement and storage processes, were not estimated because nurses and doctors shared a small sparsely furnished space on the ward at each hospital; many supplies were procured by parents; and secretarial/administrative and some hygiene activities were performed by the nurses and doctors in the process of delivering care. Fixed costs including space/rent and utility costs were also not quantified as the hospitals had no data and no historical data was available at Ministry of Health. Both hospitals are public facilities and the Ministry of Health was responsible for their utility bills. Overhead costs were also excluded as the hospitals' administrative and financial departments played minimal role in the provision of care for new-borns.

Lastly, the use of the micro-costing approach has its own limitations especially in settings with limited clinical data capture facilities as is common in low-resource settings. Nevertheless, the use TDABC approach to collect data reduced potential limitation of this costing method. Moreover, the use of sensitivity analysis addresses this limitation as it shows no substantial differences in the overall costs and costs per new-born at both hospitals.

CONCLUSION

Inpatient neonatal services are expensive, labour-intensive and require a well-organised health system and reimbursement structure for effectiveness and sustainability. Understanding the process of care and cost implications is essential for service appraisal, decision-making on pricing, priority setting and targeting funds to areas that will maximize health outcomes. Micro-costing is rigorous and requires significant investments, however, it can be adapted and used in low-resource settings as part of quality evaluation process to reveal actual utilization of resources and guide investment and quality improvement efforts. This work provides baseline cost data for future economic evaluations of neonatal services in Ghana and similar settings.

ACKNOWLEDGEMENT

We thank all nurses and doctors who were working at the study sites in 2016. We are grateful to families who participated in the study.

REFERENCES

1. UNICEF. The neonatal period is the most vulnerable time for a child. Neonatal Mortality. 2018.https://data.unicef.org/topic/child-survival/neonatal-mortality/
2. WHO. Every newborn: an action plan to end preventable deaths. Geneva; 2014 www.who.int/about/licensing/copyright_form/en/index.html
3. Mangham-Jefferies L, Pitt C, Cousens S, Mills A, Schellenberg J. Cost-effectiveness of strategies to improve the utilization and provision of maternal and newborn health care in low-income and lower-middle-income countries: A systematic review. *BMC Pregnancy Childbirth*. 2014;14(243):1–23.
4. Baqui AH, El-Arifeen S, Darmstadt GL, Ahmed S, Williams EK, Seraji HR, et al. Effect of community-based newborn-care intervention package implemented through two service-delivery strategies in Sylhet district, Bangladesh: a cluster-randomised controlled trial. *Lancet*. 2008;371(9628):1936–44.
5. Kirkwood BR, Manu A, ten Asbroek AH, Soremekun S, Weobong B, Gyan T, et al. Effect of the Newhints home-visits intervention on neonatal

mortality rate and care practices in Ghana: a cluster randomised controlled trial. *Lancet*. 2013 ;381(9884):2184–92.

6. Renfrew MJ, McFadden A, Bastos MH, Campbell J, Channon AA, Cheung NF, et al. Midwifery and quality care: Findings from a new evidence-informed framework for maternal and newborn care. *Lancet.* 2014;384(9948):1129–45. http://dx.doi.org/10.1016/S0140-6736(14)60789-3
7. Dickson KE, Simen-Kapeu A, Kinney M V., Huicho L, Vesel L, Lackritz E, et al. Every Newborn: Health-systems bottlenecks and strategies to accelerate scale-up in countries. *Lancet.* 2014;384(9941):438–54.
8. WHO and UN Partners. Country statistics and global health estimates. Global Health Observatory. 2015. http://who.int/gho/mortality_burden_disease/en/
9. Zea-Vera A and Ochoa TJ. Challenges in the diagnosis and management of neonatal sepsis. *J Trop Pediatr.* 2015;61(1):1–13 doi: 10.1093/tropej/fmu079
10. Wang H, Liddell C., Coates M., et al . Global, regional, and national levels of neonatal, infant, and under-5 mortality during 1990-2013: a systematic analysis for the Global Burden of Disease Study 2013. *Lancet*. 2014 ;384(9947):1–260.
11. Bosomprah S, Ragno P, Gros C and Banskota H. Health insurance and maternal, newborn services utilisation and under-five mortality. *Archives of Public Health.* 2015;73:51 https://doi.org/10.1186/s13690-015-0101-0
12. Ansah EK, Narh-Bana S, Asiamah S, et al. Effect of Removing Direct Payment for Health Care on Utilisation and Health Outcomes in Ghanaian Children: A Randomised Controlled Trial. *PLOS Med.* 2009; 6(1): e1000007. doi:10.1371/journal.pmed.1000007
13. UNICEF. Ghana: Neonatal and Child Health Profile. 2016. https://data.unicef.org/country/gha/
14. Enweronu-Laryea CC, Andoh HD, Frimpong-Barfi A, Asenso-Boadi FM. Parental costs for in-patient neonatal services for perinatal asphyxia and low birth weight in Ghana. *PLoS ONE*. 2018;13(10): e0204410. https://doi.org/10.1371/journal.pone.0204410
15. Kaplan S. R, Anderson R. S. Time-Driven Activity-Based Costing. *Harv Bus Rev*. 2004 https://hbr.org/2004/11/time-driven-activity-based-costing
16. Kaplan RS, Porter ME. The Big Idea- How to solve the cost crisis in health care. *Harv Bus Rev*. 2011;89(9):47-64.
17. Akhavan SB, Ward MBA L, Bozic KJ, Akhavan S, Ward L, Bozic KJ, et al. Time-driven Activity-based Costing More Accurately Reflects Costs in Arthroplasty Surgery Clinical Orthopaedics and Related Research. *Clin Orthop Relat Res*. 2016;474:8–15.
18. Keel G, Savage C, Rafiq M, Mazzocato P. Time-driven activity-based costing in health care: A systematic review of the literature. *Health Policy*. 2017;121:755–63.
19. Jain R, Grabner M, Onukwugha E. Sensitivity Analysis in Cost-Effectiveness Studies. *Pharmacoeconomics.* 2011;29(4):297–314. .
20. Merrifield J. Sensitivity analysis in benefit cost analysis: a key to increased use and acceptance. *Contemp Econ Policy*. 1997;15(3):82–92. http://doi.wiley.com/10.1111/j.1465-7287.1997.tb00480.x
21. Pannell J. D. Sensitivity analysis of normative economic models: Theoretical framework and practical strategies. *Agric Econ*. 1997;16:139–52.
22. Cömert S, Ağzıkuru T, Akin Y, Telatar B, Tan PD, Ergen SG, and Dervişoğlu P. The Cost Analysis of Preterm Infants from a NICU of a State Hospital in Istanbul. *Iran J Pediatrics*. 2012;22(2):185–190.
23. Institute of Medicine (US) Committee on Understanding Premature Birth and Assuring Healthy Outcomes; Behrman RE, Butler AS, editors. Preterm Birth: Causes, Consequences, and Prevention. Washington (DC): National Academies Press (US); 2007. D, A Systematic Review of Costs Associated with Preterm Birth. Available from: https://www.ncbi.nlm.nih.gov/books/NBK11391/
24. Ahearne CE, Boylan GB, Murray DM. Short and long term prognosis in perinatal asphyxia: An update. *World J Clin Pediatr*. 2016 Feb 8;5(1):67-74. doi: 10.5409/wjcp.v5.i1.67
25. Adei-Atiemo E, Rodrigues O, and Badoe E. "Classification and Risk Factors for Cerebral Palsy in the Korle Bu Teaching Hospital, Accra: A Case−Control Study," *Pediatrics*. 2015;135:S7. doi: 10.1542/peds.2014-3330K
26. Halloran D, McClure E, Chakraborty H, et al, Carlo W. Birth asphyxia survivors in a developing country. *J Perinatology*. 2009;29(3):10.1038/jp.2008.192 doi:10.1038/jp.2008.192.
27. Islam MK, Gerdtham. The costs of maternal–newborn illness and mortality. Moving towards universal coverage Issues in maternal–newborn health and poverty. World Health Organization. 2012. who.int/iris/bitstream/handle/10665/43516/9241594497_eng.pdf
28. Bloom DE, Fink G. The Economic Case for Devoting Public Resources to Health. IZA Policy Paper. 2013, No. 57, Institute for the Study of Labor (IZA), Bonn

29. Lawn JE, Kinney M, Lee AC, Chopra M, Donnay F, Paul VK, Bhutta ZA, Bateman M, Darmstadt GL. Reducing intrapartum-related deaths and disability: can the health system deliver? *Int J Gynaecol Obstet*. 2009;107 Suppl 1:S123-40, S140-2. doi: 10.1016/j.ijgo.2009.07.021.
30. Wallander JL, Bann C, Chomba E, et al. Developmental Trajectories of Children with Birth Asphyxia through 36 Months of Age in Low/Low-Middle Income Countries. *Early Hum Dev*. 2014:90(7);343–348. doi.org/10.1016/j.earlhumdev.2014.04.013
31. Ogata JFM, Fonseca MCM, Miyoshi MH, Almeida MFB, Guinsberg R. Costs of hospitalization in preterm infants: impact of antenatal steroid therapy. *Journal de Pediatria*. 2016; 92(1):24-31
32. Lambon-Quayefio M, Owoo NS. Determinants and the impact of the National Health Insurance on neonatal mortality in Ghana. *Health Econ Rev*. 2017;7:34. doi:10.1186/s13561-017-0169-z.
33. George Keel, Carl Savage, Muhammad Rafiq, Pamela Mazzocato, Time-driven activity-based costing in health care: A systematic review of the literature. *Health Policy*. 2017; 121(7): 755-763
34. Jacobs P, Roos NP. Standard cost lists for healthcare in Canada: issues in validity and inter-provincial consolidation. *Pharmacoeconomics.* 1999;15(6): 551-560.
35. Drummond MF, Sculpher MJ, Torrance GW, O'Brien BJ, Stoddart GL. Methods for the economic evaluation of health care programmes. Oxford: Oxford University Press; 2005. Brouwer W, Rutten F, Koopmanschap M. Costing in economic evaluations. In: Drummond M, McGuire A (Ed). Economic evaluation in health care: merging theory with practice. Oxford: Oxford University Press; 2001. p. 68-93
36. Broughton EI, Gomez I, Sanchez N, Vindell C. The cost-savings of implementing kangaroo mother care in Nicaragua. Revista panamericana de salud publica. *Pan American Journal of Public Health*. 2013;34(3):176–182
37. Barnett PG. An improved set of standards for finding cost for cost-effectiveness analysis. *Med Care*. 2009;47(7 Suppl 1):S82-8.